JOURNAL OF THE INSTITUTION OF CIVIL ENGINEERS.

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ORDINARY MEETING.

19 December, 1939.

[truncated] CLEMENT DANIEL MAGGS HINDLEY, K.C.I.E., M.A., President, in the Chair.

The Council reported that they had recently transferred to the class of

Members.

[truncated]IL WILLIAM EDWIN BISHOP, B.Sc. [truncated]Eng.) (*Lond.*).
[truncated]RED ERNEST CRISP, M.A. (*Cantab.*).
[truncated]NSER DENNIS, B.E. (*Sydney*).
ANGUS ANDERSON FULTON, B.Sc. (*St. Andrews*).
GEORGE COLIN GROVE.
AMIE AUGUSTUS RAGG, I.S.O.

And had admitted as

Students.

[truncated]FRED LORRAINE ANCKORN.
[truncated]TER ANTHONY ERIC BEAUMONT.
[truncated]D BETTESS.
[truncated]EK BILLYEALD.
[truncated]EPH RICHARD BOYLE.
[truncated]UGLAS GEORGE BULL.
[truncated]ER CAMPBELL.
[truncated]NARATNAM CANDIAH, B.Sc. (*Lond.*).
[truncated]WART CHAMPION.
[truncated]HARD CLARK.
[truncated]COLM STUART CLEMENTS.
[truncated]NALD ARTHUR COLLINS.
[truncated]N STEPHEN COOPER.
[truncated]VE CRUDDAS.
[truncated]ER JELFS CUBISON.
[truncated]N ARTHUR DAVISON.
[truncated]ES HUGH VERNON DE ALWIS.
[truncated]ALD ARTHUR DODRIDGE.
[truncated]ES CRAIG DONALD.
[truncated]RICK ALWYN EAGLE.
[truncated]BERT NICOLL EASTON.
[truncated]UGLAS HENRY ELLISON.
[truncated]RRY WOLSTENHOLME ELTON.
IVOR THOMAS SAMUEL ESSERY, B.Sc. (*Birmingham*).
ALFRED GRAVESTON EVES.
MALCOLM DUDLEY EWEN.
JOHN FREDERICK FLUDE.
RONALD HARRY FRAMPTON.
EDWARD JOHN FRASER.
FRANCIS ROBERT FULCHER.
RONALD GEORGE FUTCHER.
GERALD GREENHALGH.
JOHN ALBERT HARDING.
PETER HARDY.
COLIN HARTLEY.
JOSEPH SIMMOND HAWKES.
AENEAS ALEXANDER HENDERSON.
RONALD HODGES.
ALBION TOLSON HUTCHINSON.
DAVID ROSS HYETT.
STANLEY JAMES.
RODERICK NEVILLE WINSTANLEY KAY.
PETER GEORGE KENNETH KNIGHT.
WILFRED THOMAS KNIGHT.
WILFRID WILLIAM LAWSON.

Oliver Walter Ferriby Leach.
Kenneth Leake.
William Bouvard McLusky.
Parshotamlall Jankipershad Madan.
Raymond Stanley James Martin.
John Reid Munro.
David Peter Musgrave.
Duncan Herbert Nicholson.
Ivan Kinnersley Nixon.
Robert Walmsley Peel, B.A. (*Cantab.*).
Norman Brian Platt.
Richard Christopher Quinlan, B.E. (*National*).
Philip Rees, B.Sc. (Eng.) (*Lond.*).
Kenneth Sydney Roberts.
Douglas Gordon Robertson.
John Carter Robson.
Thomas Denys Stafford Rowland.
Douglas John Sandlin.
Jack Scott.
Thomas Basil Smith.
William Elliot Smith.
Robin Stelfox.
Theodore William Stokes.
Geoffrey Swales.
David Anthony Taunt.
Frank Lockwood Terrett.
Percy Holywell Thompson.
John Race Tully.
Ainslie John Turner.
Alwyn Peter Turner.
Alan Charles Twort.
Franz Stefan Max Weinberg.
Peter Dorel Wells.
William Stanley Whittingham.
Leslie Ernest Williams.
Walter Donald Winkworth.
Albert Walter Wright.

The Scrutineers reported that the following had been duly elected as

Member.

Thomas Henry Hogg, B.A.Sc., D.Eng. (*Toronto*).

Associate Members.

Allan Harry Beckett, B.Sc. (Eng.) (*Lond.*), Stud. Inst. C.E.
Colin Donald Brereton, B.Sc. (Eng.) (*Lond.*), Stud. Inst. C.E.
James Burdon, Stud. Inst. C.E.
Alec Ashley Chapman, Stud. Inst. C.E.
John Felix Salter Chapman, Stud. Inst. C.E.
Albert Francis George Coppen, Stud. Inst. C.E.
Charles Edmund Day.
Frederick Studdert Douglas, B.Sc. (Eng.) (*Lond.*).
Eric Arthur Elkerton, B.Eng. (*Liverpool*), Stud. Inst. C.E.
Mary Isolen Fergusson, B.Sc. (*Edin.*), Stud. Inst. C.E.
Robert Desmond Fitzgerald, Stud. Inst. C.E.
John Wilson Fletcher, B.Sc. (*Glas.*), Stud. Inst. C.E.
Allan John Gerrard, Stud. Inst. C.E.
Ian Crawford Grafton, Stud. Inst. C.E.
Harold Vincent Hill, M.Sc. (*Bristol*), Stud. Inst. C.E.
Graham Stobart Hook, M.A. (*Cantab.*), Stud. Inst. C.E.
Bryan Warden Jackson, Stud. Inst. C.E.
Oliver Kipps, B.Sc. (*Birmingham*), Stud. Inst. C.E.
Archibald Leitch, Jun., B.Sc. (*Gla*[illegible] Stud. Inst. C.E.
John Coventree Moncrieff, Stud. I[illegible] C.E.
James Henry Morton, Stud. Inst. C[illegible]
Christopher Fowler Mulvany, Lie[illegible] Col., R.E.
Jean Laurence Nairac, B.A. (*Canta*[illegible] Stud. Inst. C.E.
Frederic Thomas William Nix[illegible] Stud. Inst. C.E.
John Charles North, B.E. (*N*[illegible]*Zealand*), Stud. Inst. C.E.
Iain Hamish Ogilvie, B.Sc. (*Edi*[illegible] Stud. Inst. C.E.
Norman Keith Rose, B.Sc. (E[illegible] (*Lond.*), Stud. Inst. C.E.
Peter Roy Somerville Russell, St[illegible] Inst. C.E.
Richard Russell Sarginson, B.I[illegible] (*Liverpool*), Stud. Inst. C.E.
Robert Shutt, Stud. Inst. C.E.
Harry Simmons, Stud. Inst. C.E.
Robert James Tait, Stud. Inst. C.E.
Reginald Wallace, B.Sc. Tech. (*M*[illegible]*chester*), Stud. Inst. C.E.
John Matthew Warrington, St[illegible] Inst. C.E.
Stuart Geoffrey Webster, Stud. I[illegible] C.E.
John Rennie Whitehead, Stud. Inst. [illegible]

BRITISH-AMERICAN ENGINEERING CONGRESS, 1939.

The following Paper, dealing with British methods, was to have been esented at the British–American Engineering Congress at New York September, 1939, and was therefore primarily prepared for reading fore American engineers.

"Advances in Construction-Methods and Equipment."

By William Storey Wilson, M.C., B.Sc., M. Inst. C.E.

TABLE OF CONTENTS.

Introduction.

e title of this Paper suggests that the subject-matter is likely to comprise ch things as a description of the most modern excavating and concreting chinery, of recent progress in the chemical consolidation of ground, of sh applications of the well-point de-watering system, and other advances construction methods and equipment. Plant manufacturers and ecialists have already written so extensively on such subjects that no ology is necessary for the complete omission of any reference to them in s Paper. It is proposed instead to deal with more unusual and less ndardized methods of construction and equipment as employed on a mber of contracts recently carried out.

In Great Britain to-day it is quite usual practice for a civil engineering ntractor to carry out practically the whole of a contract with his own ganization. The same contractor may be found sinking caissons; nstructing cofferdams; driving piles and tunnels; building chimneys; rying out masonry work, brickwork, and concrete work in all its forms; cting, riveting, welding, and painting steelwork in bridges and other

structures; making roads; laying railway tracks; and generally doi everything that comes his way on a large civil engineering contract. It also usual for the contractor to design the temporary works necessary his contract and to determine the methods of construction to be employ Consequently he is given considerable freedom in the design of cofferdar caissons, centering, piling plant, temporary stagings, and any spec equipment required. For this reason most contractors have on their sta a number of qualified engineers, and it is not unknown for the engine responsible for the design of a work to discuss some of their proble with the contractor.

The various temporary works and methods of construction describ in this Paper are therefore those which were mainly the responsibility the contractor both as regards design and execution.

Chelsea Bridge.

The original Chelsea bridge over the river Thames, which was opened traffic in 1857, was a suspension-bridge, having a centre span of 352 fe The suspension-cables consisted of two groups of three wrought-i chains. The new bridge recently built to replace it is also a suspensi bridge, but of the self-anchored type with wire-rope cables. The n river piers are practically in the same position as were the old piers. is proposed to describe some of the demolition and construction-meth employment.

Demolition of the Old Bridge.

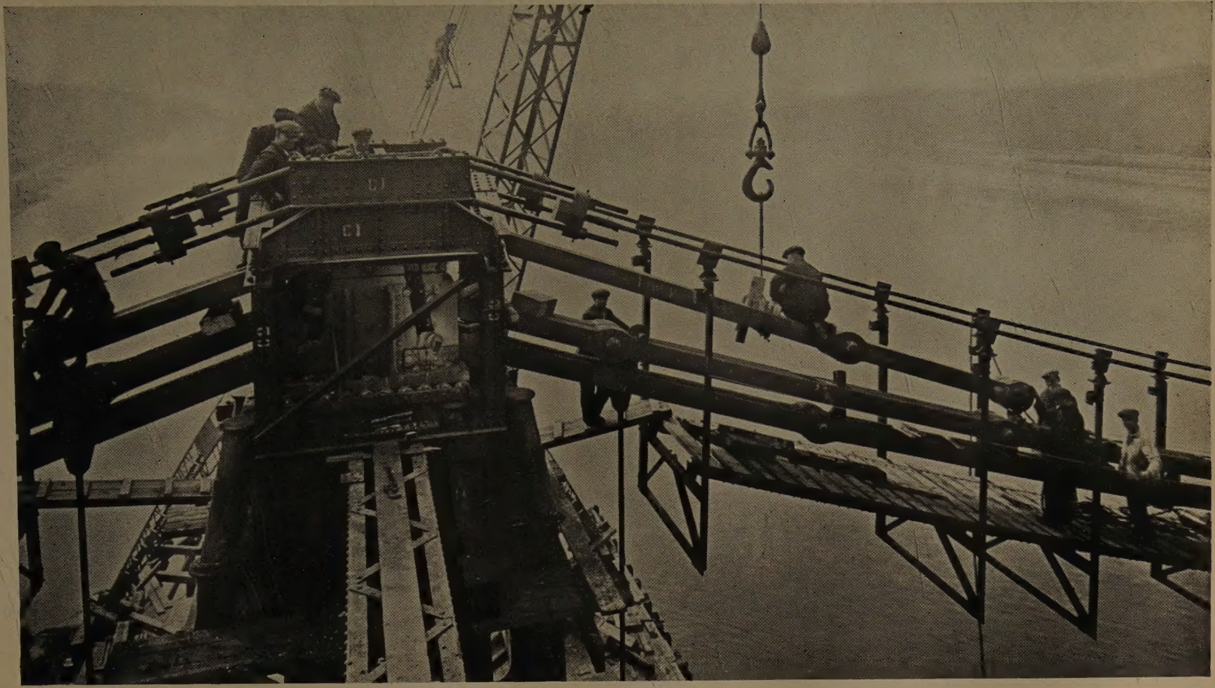
A temporary suspension-footbridge was erected under each group three chains. The ropes were 2·156 inches in diameter, with a break load of 200 tons. The two ropes to each bridge were broken at the tow the rope ends being provided with a socket sweated on and a U-bolt c nexion with bronze nuts. A steel frame was attached to the top of e tower, and was provided with anchor-pins, over which the U-bolts pas thus giving an easy means of adjusting the sag of the ropes.

The deck of the old bridge was removed by quite normal methods, it is therefore proposed to confine the description to the dismantling of suspension-chains. Working from the suspension-footbridge, the chain was wedged up from the centre chain until the stress on the cl was removed and it lay inert on the centre chain. The link-pins were t removed and the chain dismantled link by link.

The centre chain was in like manner wedged up from the bottom cl and dismantled.

This left the bottom chain carrying only its own weight. Packs inserted between the deck of the temporary suspension bridge and the ch and when these had been placed in position from end to end, the stress

Fig. 1.



DEMOLITION OF CHELSEA BRIDGE: REMOVING TOP CHAIN AND ANCHORAGE AT TOP OF TOWER.

Fig. 5.

CHELSEA BRIDGE: PLACING REINFORCED-CONCRETE FRAME D IN PIER COFFERDAM.

emoved from the chain by transferring its weight to the temporary bridge. 'his was done by screwing up the nuts on the U-bolts about 6 inches at ach tower, so that the chain lay slack on the deck of the suspension-bridge ; he load on each rope was approximately 45 tons. The link-pins were then emoved and the chain dismantled link by link.

The whole of the chains, which weighed approximately 500 tons, were emoved in 9 working days, and the temporary suspension-bridges were ompletely dismantled 3 days later. The work in progress is shown in *'ig. 1.*

'ier Cofferdam.

The size of the dam was determined by the size of the pier base. The iside dimensions of the dam were 106 feet $3\frac{3}{4}$ inches long by 26 feet $8\frac{1}{4}$ inches ide, the odd dimensions being determined by the pitch of the piling dopted.

The top level of the dam was at elevation + 19·00 O.D. The level of ie foundation was specified to be at elevation — 40·00 O.D., but provision ad to be made for excavating to a greater depth if the engineer so required ; was therefore deemed prudent to drive the sheet-piling to elevation - 50·00 O.D. The length of the piles was consequently 69 feet. The dam as to be driven around the old pier, which was more or less on the same entre-line as the new pier. In order to give adequate room for demolition f the old pier and construction of the new pier, it was decided to design ie dam with all-steel frames. Dorman, Long KIII-section piling, having weight of 32·56 lb. per square foot and a section modulus of 31·29 inches er foot run of dam, was adopted.

The question of the pressure for which the dam was to be designed was onsidered, and, although the strata was clay from level — 19·00 O.D. ownwards, it was decided to design for hydrostatic pressure down to undation-level at elevation — 40·00 O.D. This assumption was too onservative and did not obtain in practice. In the design stage it was onsidered that with a tidal river and the flexibility of the piling, the breathing " of the dam might break the contact between the steel piling id the clay, and permit a film of water to find its way down and exert ydrostatic pressure on the dam.

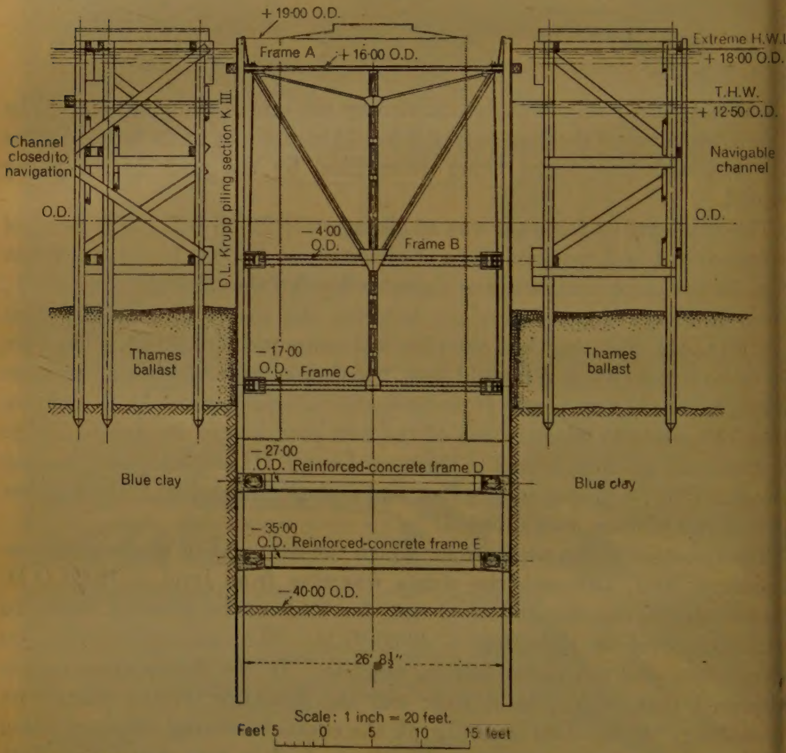
A rough calculation showed that five frames would be required, lettered r reference A, B, C, D, and E, from the top downwards.

After removal of the top of the old pier, a convenient level for frame A as determined at + 16·00 O.D. It was desirable to obtain as great a acing as possible between frames A and B in order to receive the maxi-um benefit in guiding the piles during driving, but at the same time it as necessary to keep frame B above low-water level. The level of frame B as therefore determined at elevation — 4·00 O.D. The remainder of the ames were then spaced so as to divide the load as equally as possible nongst them, which meant that frame C was at — 17·00 O.D., frame D

was at − 27·00 O.D., and frame E was at − 35·00 O.D. As frames and E would both be situated below clay-level and both could be concret into the foundation block of the pier, it was decided to make them reinforced concrete. *Fig. 2* shows the cross-section of the cofferdam ar the general arrangement of the frames.

As construction proceeded it was found that the only leakage comi

Fig. 2.



CHELSEA BRIDGE: CROSS-SECTION THROUGH PIER COFFERDAM.

through the dam was from above clay-level. It was evident, therefor that if one of the concrete frames were made into a gutter, all the wat running down the walls of the dam could be collected and led in pipes a central sump, and thus provide a perfectly dry bottom for placi the foundation concrete. This was done with complete success. T confirm that no film of water found its way between the piling ar the clay, a series of holes were drilled through the piling, without sign water.

There was therefore no hydrostatic pressure below clay-level, and it

ery doubtful if the dam were subjected to any appreciable pressure from he clay.

The holes which were drilled through the piling were closely watched, nd there was no sign of any tendency for the clay to squeeze through these oles. Further, two piles became de-clutched during driving, forming a ap which widened out to a width of some 2 feet and extended from the rst concrete frame at elevation — 27·00 O.D. to the foundation bed. his clay face stood unsupported for a considerable period, and there was o sign of movement of the exposed face. Again, when the bottom conrete frame was cast up against the piling, it was noticed that, as the oncrete set, the shrinkage caused it to come away from the piling, leaving small but definite space between the piling and the concrete; as far as ould be seen, the piling did not deflect and close this space as the excavation as carried deeper. It is reasonably certain, therefore, that this frame did ot take any appreciable load.

This would appear to give some confirmation to Bell's investigations on ay pressures, and that there is a critical depth for clay, above which ere is no active lateral pressure.

The two concrete frames D and E were left in position and concreted to the pier foundation block. The steel struts of frame C were also ncreted into the pier shaft, and afterwards burnt off and the face of the ier made good. As the pier, which was faced with granite blocks, was ilt up to the underside of frame B, a timber waling was fixed and blocked f the sides of the pier just below frame B. Frame B was then raised building proceeded, and during a period of neap tides the struts in is frame were removed and the waling of the frame was strutted off e pier.

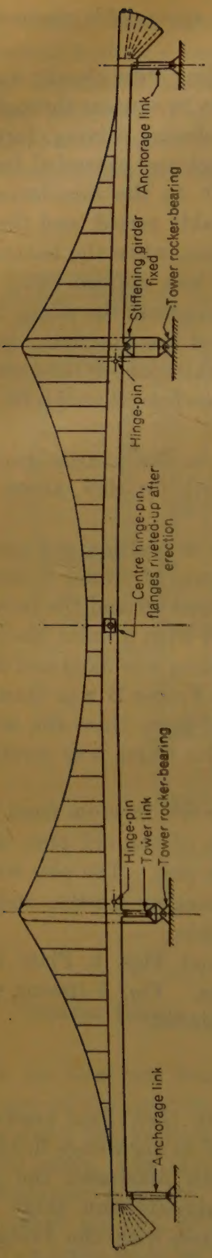
The main feature of the cofferdam design is the freedom from a large mber of timber struts during the demolition of the old pier, and the cavation, concreting, and building of the new pier. The pier was built om — 40·00 O.D. to — 4·00 O.D. without changing a strut, and above is level the amount of re-strutting was negligible.

Figs. 3, Plate 1, give details of frame B, and Figs. 4, Plate 1, show tails of one of the reinforced-concrete frames. *Fig. 5* (facing p. 275) ows the reinforced-concrete frame D being placed.

eel Erection.

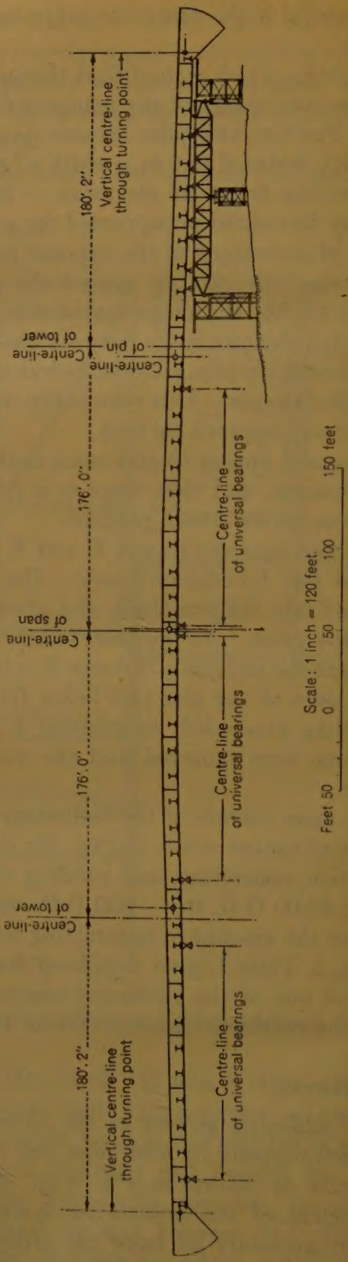
The stiffening girders in the three spans in their final position are nnected together by steel pins, and connected to anchorage links at the utments as shown in *Fig. 6* (p. 278), which illustrates the general rangement of the articulation-system. In the erection stage it was erefore necessary to have the stiffening girders with the bridge deck aced in position in four self-supporting pieces, each supported on four mporary universal bearings to permit final adjustment for the insertion the hinge-pins.

Fig. 6.



DIAGRAMMATIC ARRANGEMENT OF THE ARTICULATION-SYSTEM.

Fig. 7.



DIAGRAMMATIC ARRANGEMENT OF TEMPORARY UNIVERSAL-BEARING SUPPORTS.

CHELSEA BRIDGE.

The four sections of the bridge were erected one by one on an erection aging situated between the south pier and the south abutment, and om there floated into position; the fourth section, being erected in its ıal position, did not require to be floated.

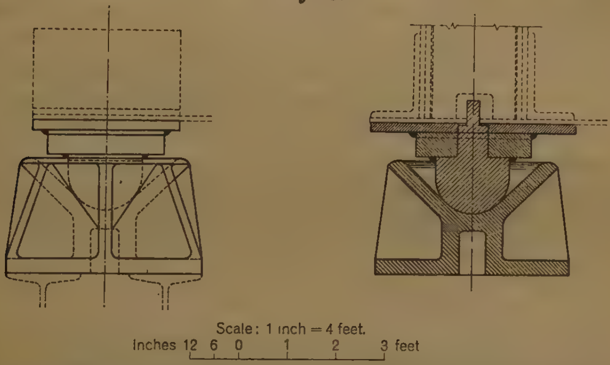
Fig. 7 shows the three sections in position on their temporary universal earings, and the fourth span on the erection staging.

rection Staging and Flotation Plant.

Four barges for floating out the sections were available, and the ection staging had therefore to be designed to suit these barges, and also permit it to be supported on piled bents to carry its own weight of 80 tons ıd that of the section of bridge, weighing 420 tons.

The staging consisted of two main girders 120 feet long at 50-foot inch centres, connected together by eight cross-girders. The main

Figs. 8.



CHELSEA BRIDGE: DETAILS OF BEARINGS ON FLOTATION PLANT.

ders were supported on four end bearings and two centre bearings, each nsisting of a spigot bearing resting in a cup-shaped casting (*Figs. 8*) ich facilitated the landing of the staging back on its supports after the npletion of a flotation, ready for the erection of the next section. mber packings were placed on the top of the main girders to receive stiffening girders during erection and riveting.

When a span had been completely erected on the staging the four rges were floated into position under it, and as the tide rose the float was ked up on long timbers on the barge decks, one under each of the eight ss-girders, and the float was towed to position in the usual way and ded on its universal bearings as the tide fell.

This arrangement is shown in Figs. 9, Plate 1.

iversal Bearings.

The temporary universal bearings are probably worth describing on ount of their simplicity. The vertical movement at each bearing was

provided by two 100-ton hydraulic jacks interconnected, and fitted wi
screw collars. The jacks were fixed to the underside of the stiffeni
girders and floated out with the span. As the tide fell and the jack-ra
came in contact with the bearing, the jacks were pumped up, and
transferred a portion of the weight of the span to the bearings and avoid
any chattering due to wave-action on the floating unit.

The universal movement in the horizontal plane was obtained
inserting two nests of rollers at right angles to each other with steel plat
below, between, and above the nests of rollers, the bottom plate bei
supported on a grillage on the top of the temporary piled bent. A grilla
was provided above the top plate to support a steel slab with spheric
seating to take the head of the jack-ram.

Figs. 10, Plate 1, show the arrangement of the bearings at the centre
the bridge. Provision had to be made here for a vertical movement
4 feet 6 inches, as after the hinge-pin connexion at the centre had be
made it was raised by this amount to enable the hanger rods to be connect
to the stiffening girder, and at a later stage in the erection the centre w
again lowered to transfer the weight to the suspension-cables. Figs. 1
Plate 1, show the bridge centre at its lowest position, and it will be not
that temporary timber packs between the bearings had to be provided
take the load at each successive run out of the jacks. The nests of rolle
enabled the adjustment of the bridge, to the exact position for the fitting
the pins, to be carried out with the greatest ease.

A Reinforced-Concrete Chimney.

The method employed in the construction of a reinforced-concre
chimney at a chemical works in London may be of interest.

The chimney has a height of 279 feet, and has an outside diameter
the bottom of 13 feet 10¾ inches and at the top of 9 feet 3 inches; the wa
thickness is 15 inches at the bottom, reducing gradually to 6 inches at t
top. The chimney is lined with firebricks.

The usual method of construction is to have three or four sets of shutte
each about 2 feet deep, and while the concrete is setting within the t
shutter, the lowest shutter is stripped and adjusted to suit the reducti
of diameter and taper, and reset at the top ready for the next lift
concrete. In order to speed up the work of construction, and to ma
use of the undoubted advantage of moving-form construction, t
mechanism described below was devised.

The moving frame consisted of six vertical "soldiers" spaced equa
around the outside circumference, and an equal number of "soldiers
around the inside circumference, each midway between the adjace
outer "soldiers." The outer "soldiers" were connected together by t
hinged link-systems in a horizontal plane forming a star shape, the upp
link-system being at the top of the "soldiers" and the lower-link syste

out the mid-point. All corresponding members in the upper and lower k-systems were connected together by bracing frames. The outer ints of the star were then connected to the inner " soldiers " and rigidly iced in a vertical plane. At two planes very near the horizontal link-stems the inner " soldiers " were connected together by adjusting screws h nuts, in the form of a hexagon.

To the lower part of the outside " soldiers " below the link-system, two s of walings, curved to correspond to the maximum external diameter the chimney, were fixed. These walings were broken and spliced ween the " soldiers ", the splice waling being connected by loose bolts rking in slotted holes. The arrangement of walings for the inside oldiers " was similar, except that the curvature corresponded to the nimum internal diameter at the top of the chimney. Vertical timber ves similar to those employed on ordinary moving-form construction re fixed to the curved walings, to form the surface of the moving shutter.

The mechanism complete was supported on the reinforcing rods by the ial type of moving-form jacks, attached to the inner and outer " soldiers " means of brackets.

The length of the links in the horizontal system were determined to e the correct thickness of concrete for the particular diameter. That is say, with the mechanism expanded at the bottom of the chimney with outside diameter of 13 feet 10¾ inches, the thickness of the concreting ice between the sets of staves was 15 inches, and in the fully-contracted idition at the top of the chimney, with an outside diameter of 9 feet nches, the concreting space was 6 inches. The movement from the ly-expanded to the fully-contracted position was obtained by the travel the nuts on the adjusting screws.

It will be seen, therefore, that by correct synchronization of the travel he vertical lifting jacks and of the adjusting screws forming the hexagon, desired taper of the chimney and the corresponding wall-thickness ld be obtained.

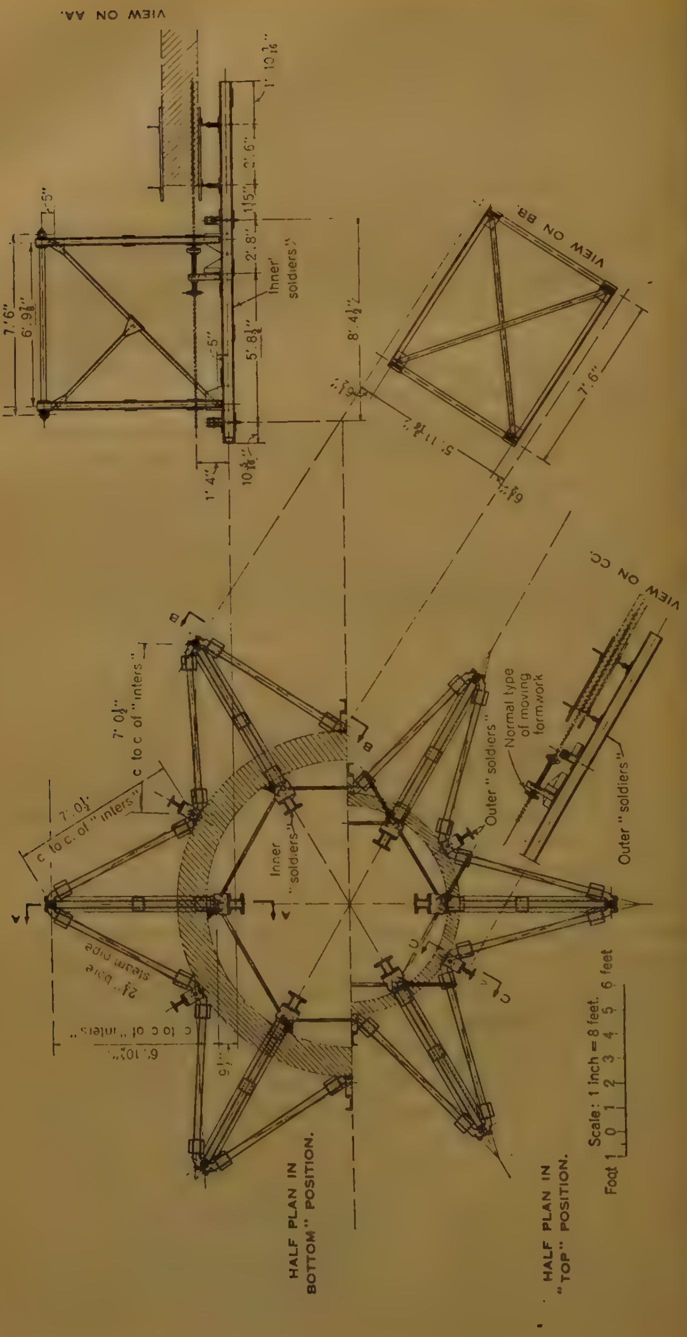
Between the panels of vertical staves there remained a space, which s a maximum at the bottom of the chimney and which tapered to zero the top of the chimney. This space was filled in by a tapered shutter ich was left behind as the mechanism was raised, additional lengths of ered shutter being added as rèquired.

The mechanism is shown in detail in *Figs. 11* and *12* (pp. 282–283), and use enabled the last 166 feet to be completed in 44 days, not counting kends.

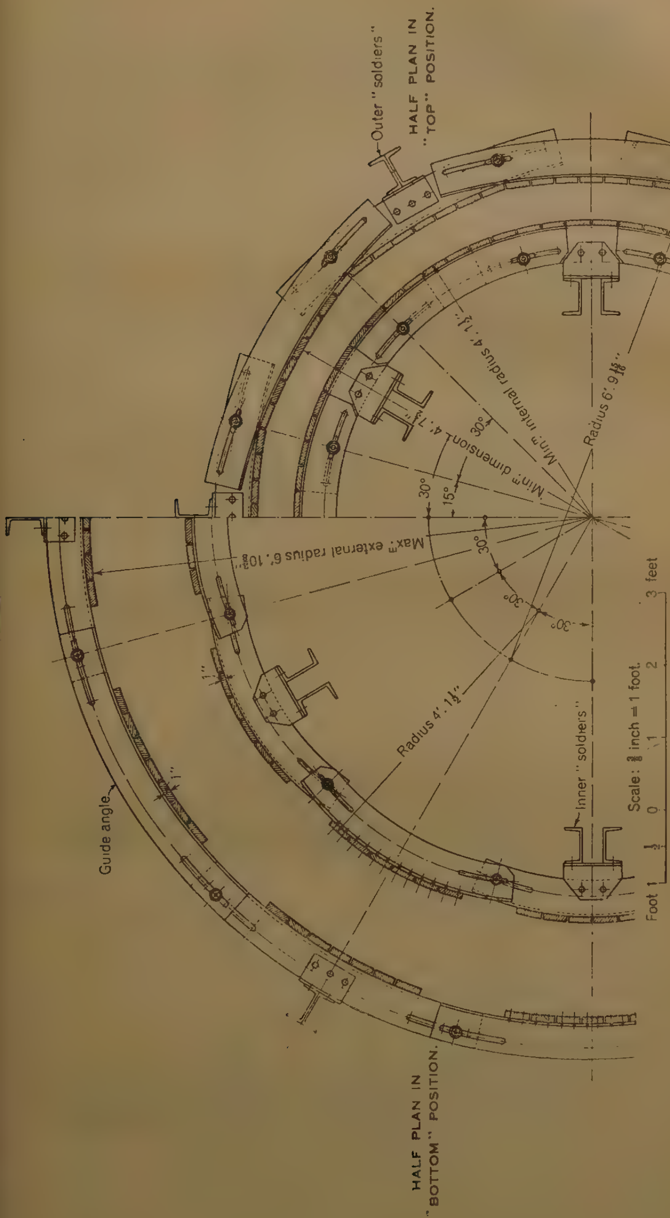
Wandsworth Bridge.

This bridge, at present in course of construction, is situated about mile upstream of Chelsea bridge, previously described. It is a deck lge of the cantilever type, having a centre span of 300 feet between

Figs. 11.

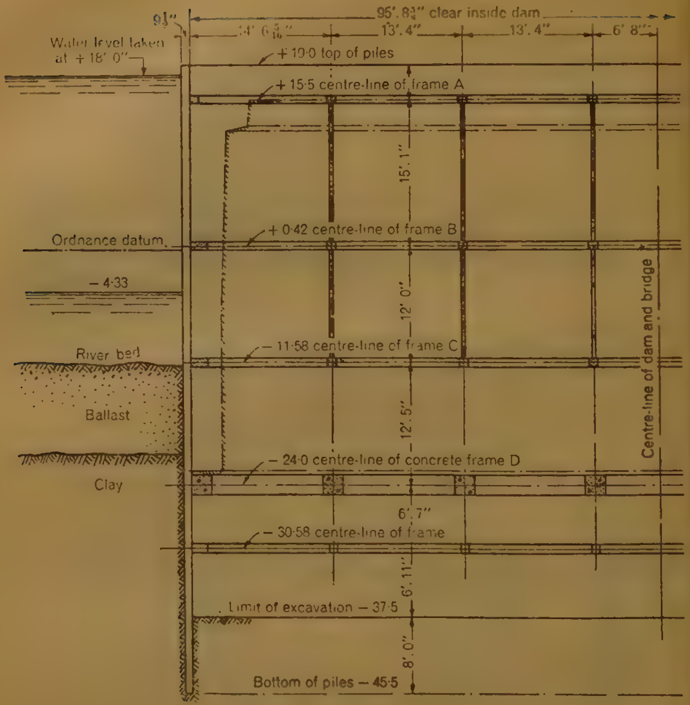


REINFORCED-CONCRETE CHIMNEY: DETAILS OF MOVING-FORM MECHANISM.

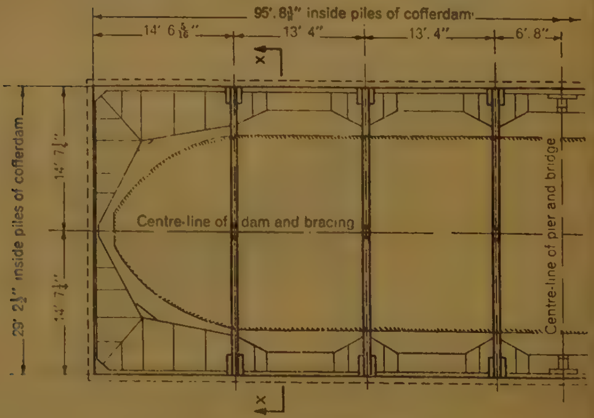


REINFORCED-CONCRETE CHIMNEY: DETAILS OF WALINGS AND STAVES OF MOVING-FORM MECHANISM.

Figs. 13.



LONGITUDINAL SECTION OF COFFERDAM.



PLAN OF COFFERDAM.

Scale: 1 inch = 20 feet.
Feet 5 0 5 10 15 20 feet

WANDSWORTH BRIDGE: GENERAL ARRANGEMENT OF PIER COFFERDAM.

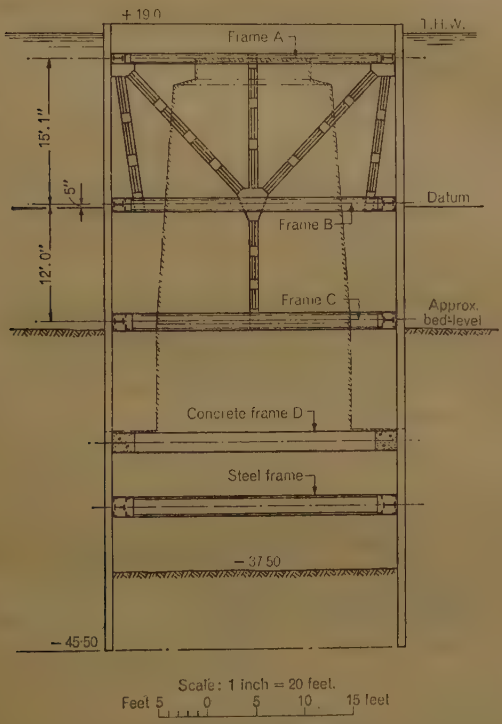
rs, the suspended span being 120 feet long and the side anchor-spans h 178 feet long.

It is not proposed to do more than describe the construction of one of pier cofferdams, which were very similar to those of Chelsea bridge, but dified in view of the experience gained on the latter.

er Cofferdam.

The piers were built inside cofferdams measuring 96 feet by 29 feet, der conditions almost identical with those experienced at Chelsea. At

Fig. 14.



SECTION XX IN *Figs. 13.*

elsea it was found that the lowest of the five frames took little, if any, d, and it was decided therefore in this case to design the cofferdam th four frames A, B, C, and D, at elevations + 15·50, + 0·42, – 11·58, d – 24·00 O.D. respectively, the top of the sheet-piling being at elevation 19·00 O.D. and the foundation-level at – 37·50 O.D. The piles were ven to elevation – 45·50 O.D. making them 64 feet 6 inches long. ame D, as in the case of Chelsea bridge, was in reinforced concrete to

form a drainage channel to carry off the leakage from the walls of t
dam, and was arranged, as before, to be concreted into the foundation sl

The distance from the fourth frame to the excavated level was 13 f
6 inches; this may appear to be an excessive height at such depth witho
strutting, but London clay is so stiff, and the piling section was so hea
that it was considered that, if any sign of deflexion in the piling beca
evident during excavation, timber strutting could readily be provid
without any danger of collapse of the dam. Furthermore, all evidence
the Chelsea bridge pier cofferdam had pointed to the fact that the fi
and lowest frame did not in practice take any load.

The engineer responsible for the work, however, desired that a fi
frame in either concrete or steel should be provided. A steel frame ma
for the other pier cofferdam, which was not so far advanced, was availab
and in order to check the loading on this frame a 100-ton jack with scr
collar was incorporated in each of three struts. This frame was fixed
position at elevation — 30·58 O.D., and as excavation proceeded the jac
were pumped up from time to time until the collars were just free. It
interesting to note that the load on the jacks was so small as to be unrea
able on the jack pressure-gauges. The arrangement of the cofferdam
shown in *Figs. 13* and *14*; the close spacing of the two lower frames
the reason given will be noted.

The other interesting change in the design of this dam was in t
make-up of the frames. *Fig. 15* show the details of frame C, which w
designed to enable the pier to be built without fouling the frame. In t
case of the Chelsea bridge cofferdams certain adjustments of the fran
had to be made during the construction of the pier, and the modif
design for Wandsworth greatly facilitated the pier building.

A New Power-Station.

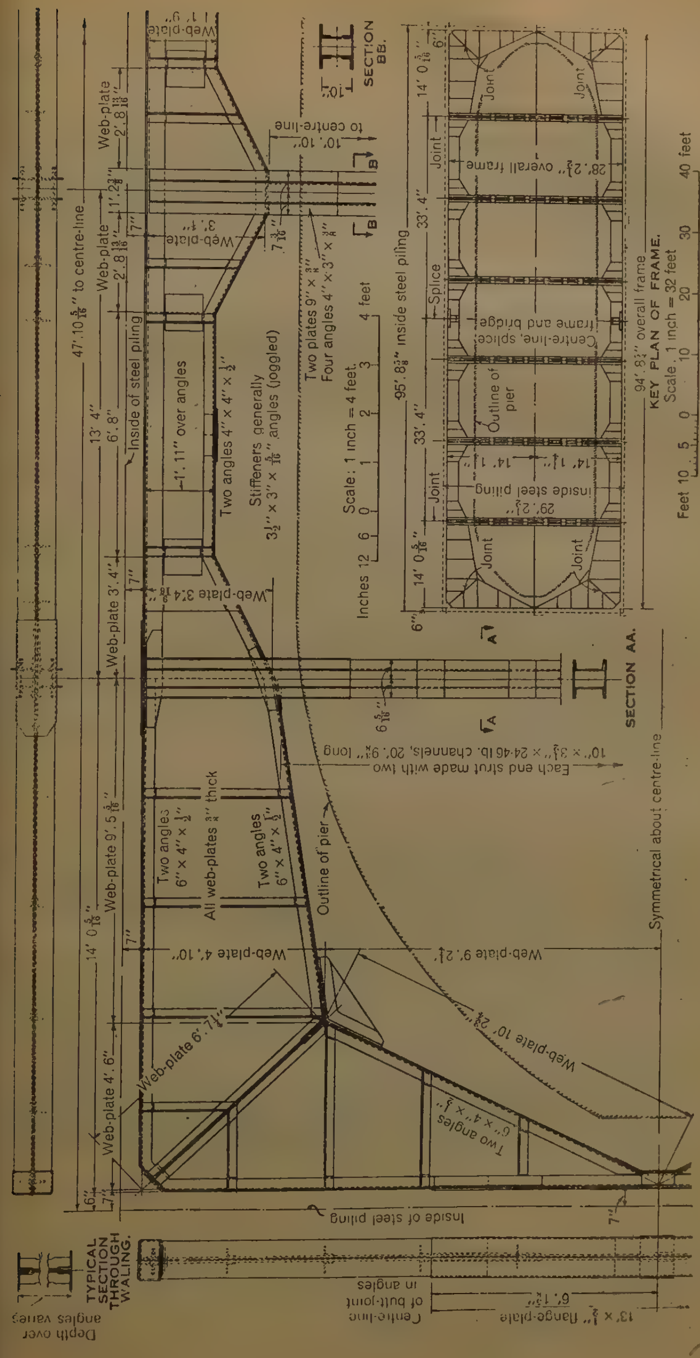
It is proposed to describe a number of the interesting and perha
novel methods employed in the construction of a power-station in southe
England.

Pump-House Cofferdam.

The site of the pump-house is situated just behind the earth emba
ment of a river, which was constructed some centuries ago. The gene
ground-level is at about + 4·00 O.D., and the top of the embankment
at elevation + 19·00 O.D., about 3 feet above the highest water-level.

The site is more or less a marsh with strata of peat, silt, sand, a
ballast over-laying water-bearing chalk at about elevation — 50·00 O.
A bore sunk into the chalk proved that the ground-water was tidal;
rose in the tube to about level + 8·00 O.D., or 4 feet above ground-le
with river-level at about + 12·00 O.D.

Figs. 15.



WANDSWORTH BRIDGE: DETAILS OF STEEL FRAME C FOR PIER COFFERDAM.

The foundation of the pump-house, built within a cofferdam, consists a mass-concrete block founded at level — 36·00 O.D., and having a thic ness of 10 feet; it is 152 feet 6 inches long by 75 feet 6 inches wide. T is surmounted by reinforced-concrete surrounding walls and cross-wa forming a series of chambers, to house screens, penstocks, pump suctio and pumps.

There were two evident construction difficulties; the building of t intricate reinforced-concrete work within the cofferdam amid a maze timber strutting, and the de-watering of the cofferdam, with the possibil of a "blow." It was therefore decided to drive the sheet-piling down ir the chalk, and although this would not prevent a large volume of wa being encountered, it would at least provide against the bottom rising duri construction.

It was further decided not to use the usual timber strutting to the da but to adopt steel frames, described hereafter, for strutting the cofferda so as to give adequate space for the construction of the reinforced-concr work. The top of the steel piling was driven to level + 8·00 O.D. provide against flooding the surrounding area should the water-le rise within the dam, and the toe to level — 52·00 O.D. to key into t chalk.

The three steel frames A, B, and C, were arranged to be at lev + 6·00 O.D., — 8·00 O.D., and — 24·00 O.D. respectively.

Trial holes showed that the ground was more or less impervious do to level — 24·00 O.D., and until the excavation approached the ballast level — 30·00 O.D. no great amount of water was expected. On the otl hand, when water was encountered it might be in quantities so considera that it would be impossible to pump the dam dry, and provision had to made in the design to meet these conditions should they arise.

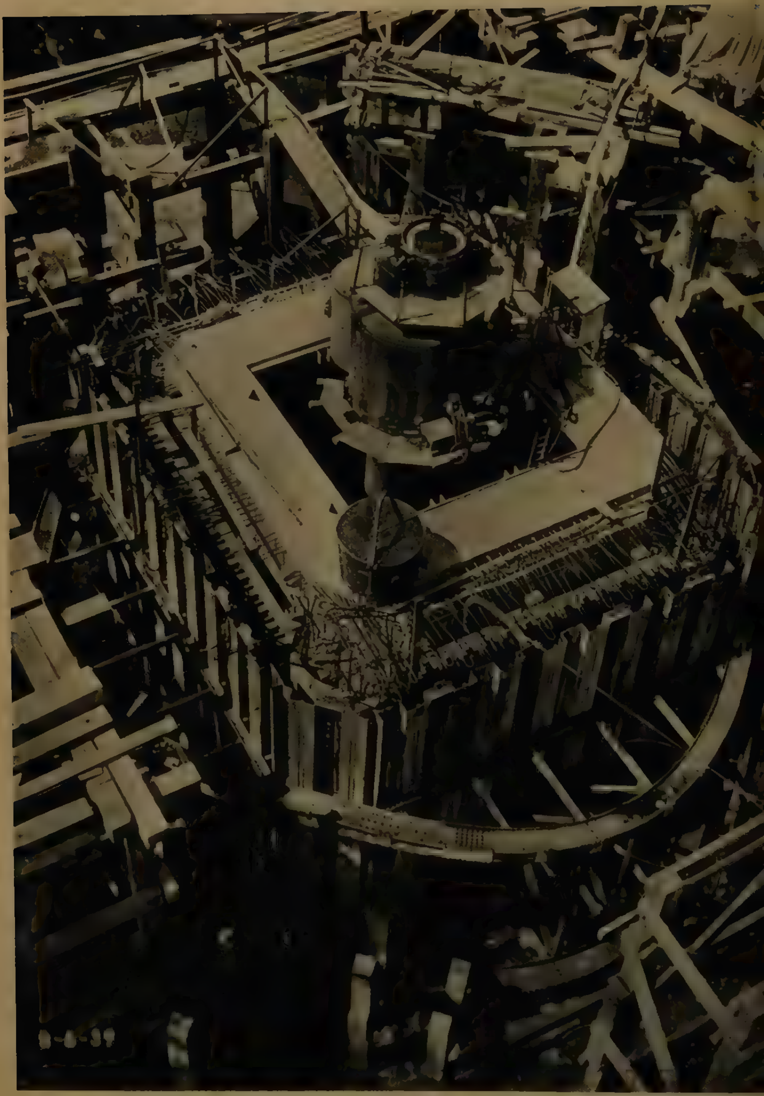
The three steel frames, which weighed about 320 tons, were design as horizontal trusses about 14 feet deep around the wall of the dam, w two intermediate struts 40 feet apart, giving three clear spaces within dam, each about 40 feet square, for grabbing.

The two top frames, A and B, braced together vertically and formin rigid boxed frame, were erected on the ground, and the sheet-piling, Dorman, Long KIII-section in 60-foot lengths, was driven around them form an enclosed dam. The frames were then picked up on lowering ge supported on four groups of timber piles previously driven. As excavat of the dam proceeded these two frames were lowered foot by foot to th final position, and were wedged hard at each pile section.

When excavation had proceeded some few feet deeper, frame C erected below the two top frames and was hung from them by screw rods at suitable points. As excavation proceeded further this frame likewise lowered. As, however, it was not known when an inrush of wa might be met, the hangers connecting this frame with the two top fran were made telescopic to enable them to be bolted up at any desired le

NEW POWER-STATION: EXCAVATION PROCEEDING IN PUMP-HOUSE COFFERDAM, WITH ALL THREE FRAMES IN POSITION.

Fig. 19.



NEW POWER-STATION: GENERAL VIEW OF CIRCULATING-WATER INLET SHAFT COFFERDAM, SHOWING WORK CARRIED OUT INSIDE DAM.

fter each lowering operation, of a foot or two at a time, the frame was edged up around its periphery in case water troubles necessitated the mainder of the excavation being carried out under water. However, as xcavation proceeded the frame was lowered without much difficulty to its esigned level, in which position it was made secure by wedging hard all und and finally bolting up the hangers.

With the frame in its designed position it was the intention to excavate own to foundation-level at — 36·00 O.D. Four 4-inch and eight 6-inch ertical-shaft electric pumps were suspended from the frames to deal with e water, all pumping to an overhead flume leading the discharge over the ank to the river.

It was feared that those pumps might not be able to cope with the flow of water, and to provide against this contingency a ballast pump as rigged up on a small pontoon, which could be lifted by the construction anes and floated inside the dam to pump out the ballast to the required undation-level, in which event the concrete foundation-slab would have ad to be placed under water. The pumps were, however, able to cope ith the inflow of water, and excavation proceeded down to the designed undation-level.

The mass-concrete slab 152 feet long by 75 feet 6 inches wide by 10 feet ick was next placed below the level of the steel frames without a single rut or pile being in the way. The bottom frame C was then removed, and e reinforced-concrete surrounding walls, the cross-walls, and the longi- dinal walls were built up to the underside of frame B. There again the einforced-concrete work, to a height of 16 feet, was built with complete eedom, and when the concrete work reached that level the two top frames and B were removed entirely, so that the whole of the remainder of the ork was carried out in the clear.

A drawing of the cofferdam arrangement is shown in Figs. 16, Plate 2, nd *Fig. 17* (facing p. 288) shows excavation proceeding with all three ames in position.

nlet-Shaft Caisson and Temporary Cofferdam.

The river inlet-shaft to the circulating-water tunnel, with its timber rash-screens, is incorporated in the reinforced-concrete coaling jetty.

A caisson 33 feet 6 inches by 30 feet was sunk in the river under com- ressed air. This caisson, with its top level at — 20·00 O.D., formed the ntrance to the inlet-shaft, and also carried four circular columns extending p to about high-water level and forming a continuation of the reinforced- oncrete jetty construction; between those four circular columns the imber trash-screens had to be fixed. With the top of the caisson at level - 20·00 O.D., and with low-water level at about — 7·00 O.D. and high- vater level at + 16·00 O.D., a cofferdam had to be provided to enable the haft to the tunnel entrance to be sunk within the caisson, and to permit he circular columns with their bracing struts, and the timber trash-screens,

to be constructed in the dry. This construction work within the cofferda
took up the whole of the available space, so as to leave no room inside t
dam for walings and struts to support the sides of the cofferdam. It
proposed to describe how this difficulty was overcome. The only appare
solution, and the one adopted, was to provide outside frames to suppo
the cofferdam, and thus leave the internal space quite unobstructed f
carrying out the work within.

The cofferdam was built of Dorman, Long KII-section piling 37 fe
6 inches long, welded together in sets of two and three piles to make un
5 feet 4½ inches and 7 feet 10½ inches wide, with a welded base-plate fitt
with a rubber seal to bear on the top of the caisson. The separate un
were connected together by means of the normal pile-clutches, and t
base-plates were suitably stepped back to enable this to be done and
ensure a good seal.

Due to the tidal range of the river the operation of lowering the caiss
to the river-bed had to be under control, with sufficient weight in t
caisson to prevent it from floating at high tide. To meet this conditi
the lowering gear had to be capable of supporting a total load of 650 to
as the difference in the weight of the caisson between high and low wa
was approximately 600 tons. Groups of timber piles to support t
lowering gear which had to carry this load were driven close to the fo
corners of the caisson, those being the most satisfactory positions for t
attachment of the lowering brackets to the caisson steelwork. In order
clear the lowering gear, the external frames to the cofferdams were design
as curved ribs with parabolic arcs, the adjacent ribs having a comm
tangent. Ties or walings were arranged along the outside face of t
cofferdam, picking up the individual piles and transmitting the load throu
hangers to the arch-ribs. The complete rib was designed as a rig
structure. Two frames were provided, 15 feet apart, at levels + 9·00 O.
and — 6·00 O.D., braced together vertically so as to give the necessa
rigidity in the vertical plane. The arrangement of the cofferdam and t
external frames are indicated in *Figs. 18*, and *Fig. 19* (facing p. 28
shows the work under construction.

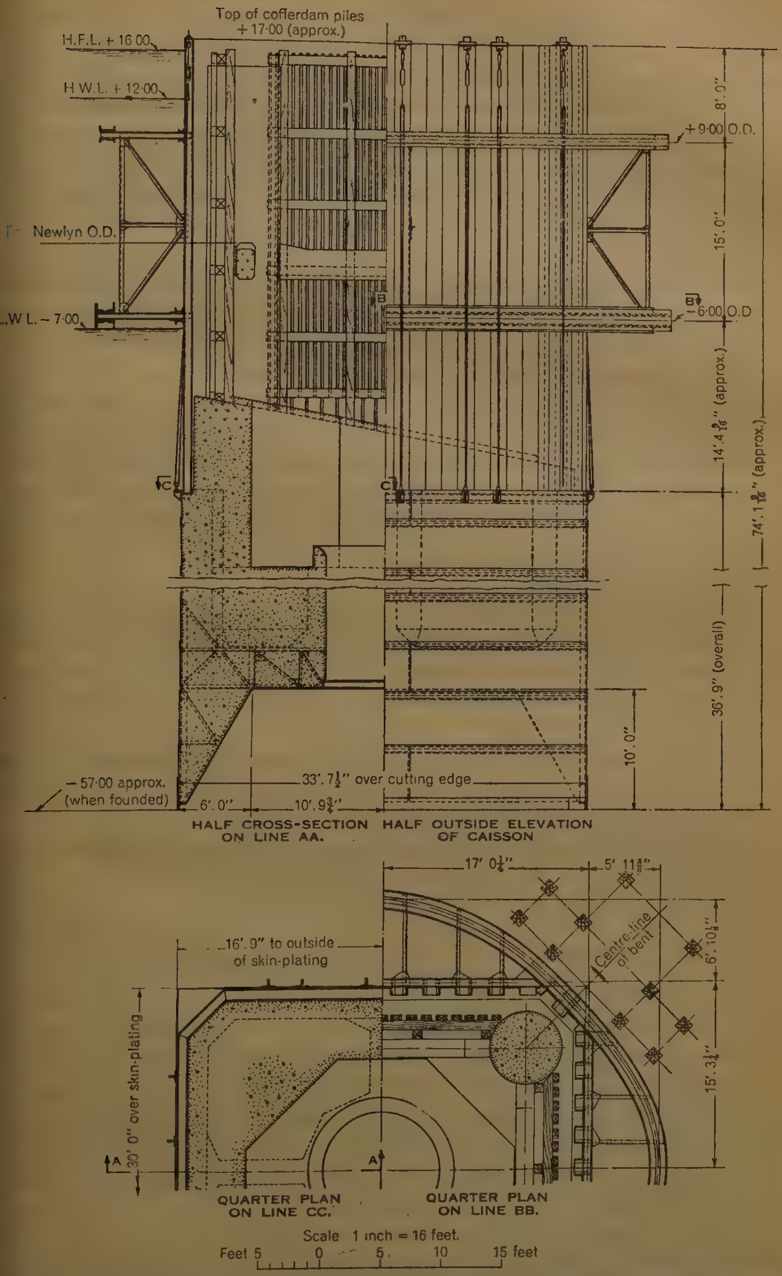
Circulating-Water Inlet-Tunnels.

The first of the two tunnels has already been driven. The shield us
was of quite normal construction and no great difficulties were encounte
during driving. The main point of interest is the shield chamber provid
at either end of the tunnel, the design and construction of which it
proposed to describe.

After completion of the pump-house foundation, and the caisson for t
inlet to the tunnel, a shaft 10 feet 9 inches in diameter was sunk below t
pump-house foundation under compressed air. This shaft was lined w
cast-iron segments, which were caulked and grouted as the work proceed

At level — 56·00 O.D. the shaft was flared out until at level — 62·00 O

Figs. 18.



NEW POWER-STATION: GENERAL ARRANGEMENT OF INTAKE-SHAFT CAISSON AND COFFERDAM.

it had reached a diameter of 18 feet, and at this diameter the sinking of t shaft proceeded to level — 79·00 O.D., at which level a concrete se designed as a dome and about 4 feet thick, was placed. When this concre seal had sufficiently matured, the shaft was put under free air and the tunn shield was then erected in the shield-chamber thus provided. On the tunn side of the shield-chamber the cast-iron lining was designed so as to form removable "window" to allow the shield to be pushed forward for t driving of the tunnel. At the back of the shield-chamber a thrust-blo was built in concrete, and a number of cast-iron segments were temporari erected within and behind the shield and blocked off the concrete thrus block. The shaft was then again placed under compressed air, the cast-iro segments forming the "window" removed, and the driving of the tunn commenced.

When construction has progressed sufficiently for the tunnel lining take the full reaction from the shield-jacks, the temporary cast-iron se ments were dismantled and used in front for the lining of the tunne While this work was proceeding a similar shield-chamber was built at tl bottom of the inlet-shaft out in the river, and in due course the shie worked its way forward, completing the tunnel and finishing up in the shiel chamber. The whole tunnel was then put under free air and the shie dismantled and removed.

The maximum air-pressure of about 38 lb. per square inch was reache during the placing of the concrete seal in the bottom of the shield-chambe and during the whole period of carrying out the work the maximum amou of air required did not exceed 2,000 cubic feet of free air per minute.

It is believed that had the shield-chamber been built as a horizont chamber in front of the vertical shaft, which is the usual accepted practic the quantity of air would have been some three or more times the amou actually used by the method employed.

The arrangement of the shaft and shield-chamber is shown in Figs. 2 Plate 2.

Cylinder-Lowering Gear.

The reinforced-concrete coaling jetty for the power-station is built pre-cast hollow cylinders, with steel-joist piles driven inside after foundin the cylinders being then filled in with mass concrete.

The cylinders were lowered from a temporary timber staging l hydraulic jacks with annular rams. A group of three jacks supporte from steel beams on the staging were designed to handle a cylinder weighi up to 90 tons, although the particular cylinders in question were of much lesser weight.

The lowering rods which pass through the jack-rams are notched 18-inch intervals, and split collars fitting these notches enable the load be taken either by the jacks or by the steel beams supporting them. Th

ottom ends of the lowering rods are provided with a coupling having a ft-hand screw connecting to screwed rods set in the pre-cast cutting edge f the cylinder. In operation the cylinder is supported by the rods on the teel beams; the jacks are raised by water supplied from a tank by the aid f compressed air; the load is then taken on the top split collars on the ck-rams, a hand-operated hydraulic pump being used to take the load hile the lower split collars are removed; the rams are then lowered 8 inches by the weight of the concrete cylinder itself, the water being llowed to flow back into the tank until the load is again taken on the wer split collars on the steel beams. The operation is repeated until the tting edge reaches the river bed, and continued as material is grabbed out om inside the cylinder.

When the cylinder is finally self-supporting at the required level the ds are screwed from above and disconnected from the anchor-rods in the ylinder cutting edge. The lowering rods are in convenient lengths of feet screwed into each other end to end. By this method cylinders can e lowered with great accuracy and simplicity, and the plant can be used r all sizes and types of cylinders up to the capacity of the jacks. The rangement is shown in *Figs. 21* and *22* (pp. 294–295).

arge-Jetty.

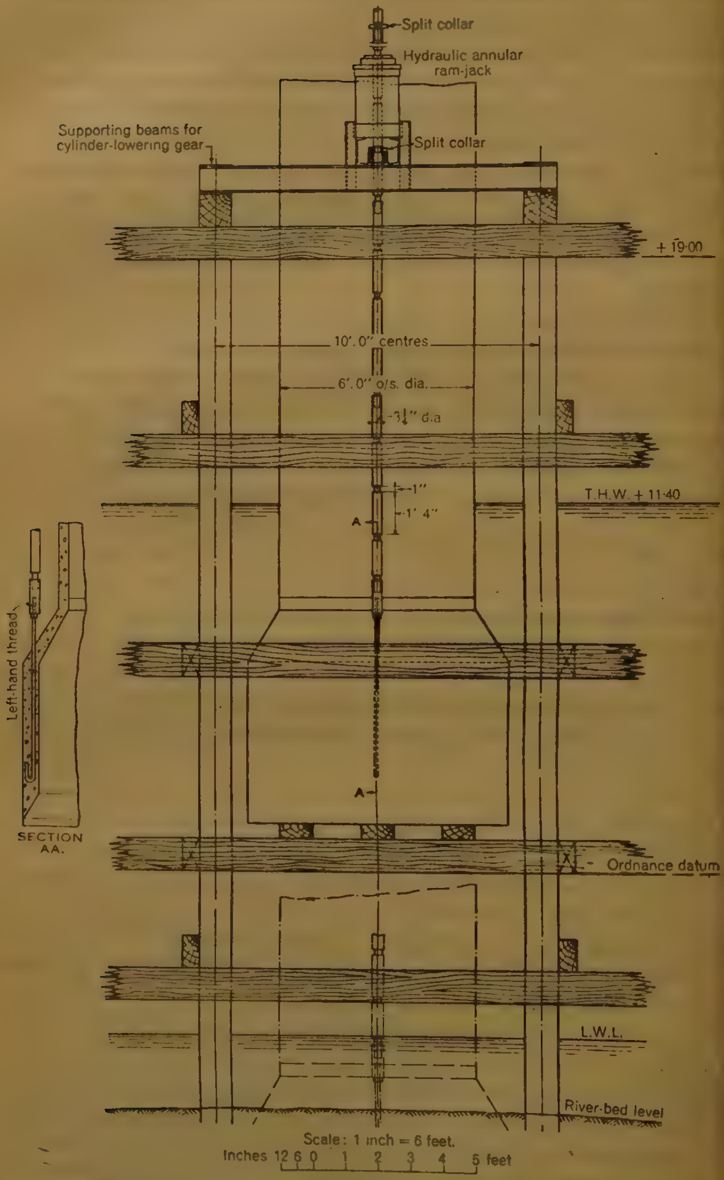
This jetty extends into the river in a circular form on a radius of 5 feet 6 inches and then merges into a straight portion parallel with the ver-bank. It is constructed of Douglas fir with piles 15 inches by inches by 60 feet long, and steel deck stringers carrying the rail acks. The pile bents are at 16-foot centres with three piles in each bent 9-foot cross-centres on the curved portion and at 12-foot 3-inch centres the straight portion.

The majority of the piles were situated between high and low water d a number in the embankment were not even accessible at high water. nly some of the piles could therefore be driven with a floating unit, and the work would be dependent on the tides, and, further, as the position- g of the piles had of necessity to be accurate to accommodate the steel ck beams (which were fabricated to exact lengths), it was decided to sign a composite piling and construction plant to carry out the whole the work from above.

The plant is shown in some detail in *Figs. 23* and *24* (pp. 296–297), d *Figs. 25* (p. 298) shows the arrangement of the jetty.

Briefly, the plant comprised an undercarriage mounted on four ball rriages which ran on bullheaded rails carried on track beams, the length of ich was determined by the exact spacing of the bents in the river, for the ter and inner rows of piles. The upper carriage consisted of two lattice- ders 60 feet long by 7 feet deep, bolted to the undercarriage to give the cessary cantilever distance from the position of the plant on the work mpleted to the next bent ahead to be driven. At the cantilever end of

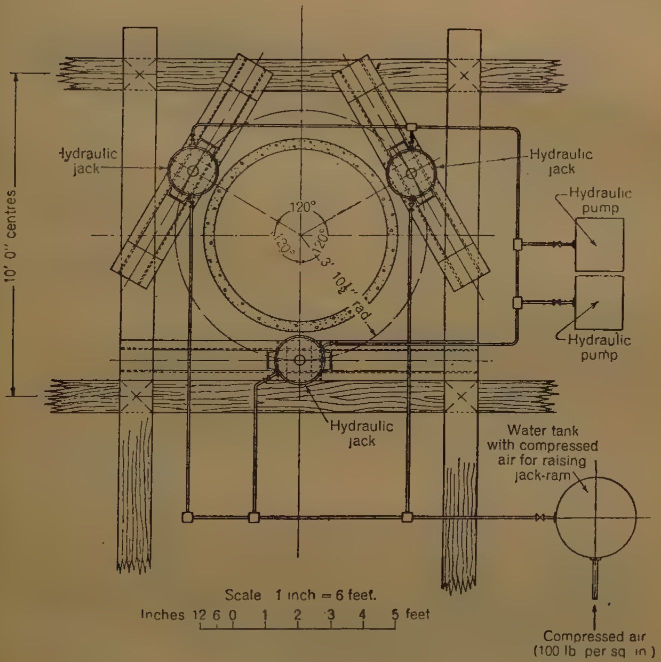
Figs. 21.



New Power-Station: Elevation of Lowering Gear for Reinforced Concrete Cylinders.

he upper carriage a braced tower about 50 feet high by 30 feet wide was rovided, carrying a set of false leaders on its front face arranged to have cross-travel of 24 feet 6 inches on a running rail at the top of the tower. The tower was provided with fixing points for the false leaders, which etermined the position of the piles in the bents on both the straight and urved portions of the jetty. The upper carriage was set and fixed to ne lower carriage at the tangent angle so that the false leaders were on

Fig. 22.



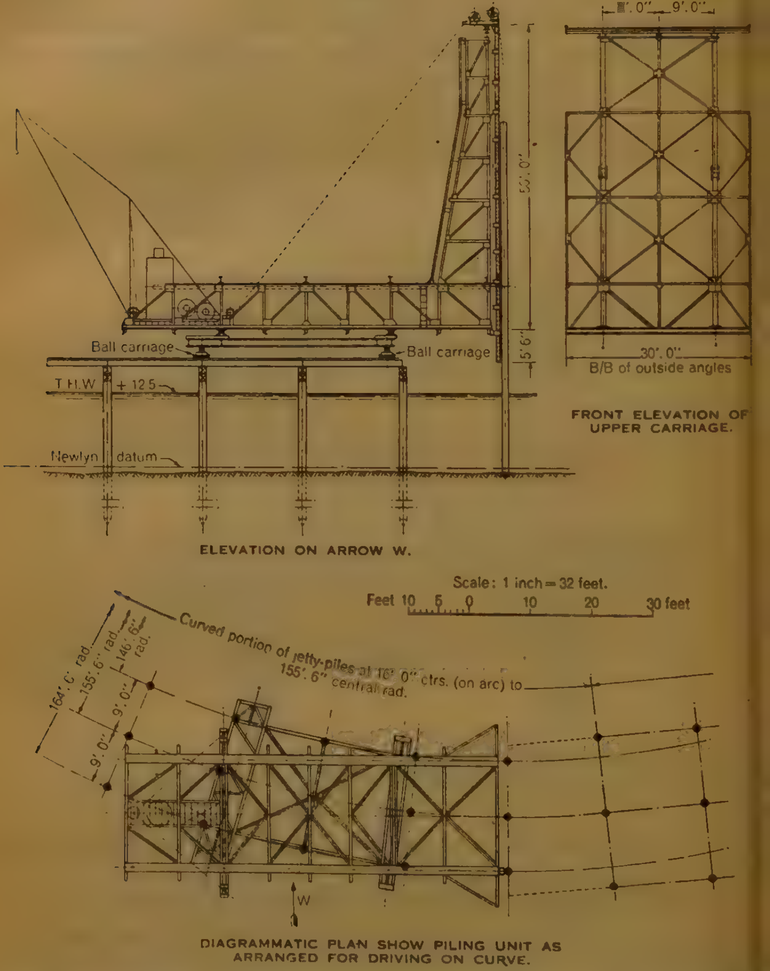
NEW POWER-STATION: PLAN OF LOWERING GEAR FOR REINFORCED-CONCRETE CYLINDERS.

e radiant; an alternative fixing was provided for driving on the raight.

The ball carriages mentioned previously were very simple and consisted two channels back to back with a short length of bullheaded rail turned at the ends and welded to the channels. Steel balls, 3 inches in diameter, ere placed between that rail and the track rail, and as the outfit was nched forward, the balls on leaving the back of the carriage were replaced front. The track rails were curved to a circle, and above the carriage ball bearing was provided to give the carriage freedom of movement in

taking the curve. Besides being provided with a single-acting steam hammer, winches, boiler, and air-compressor, the outfit had a derric crane at the back for fixing the bracing timbers and deck beams, also sid

Figs. 23.

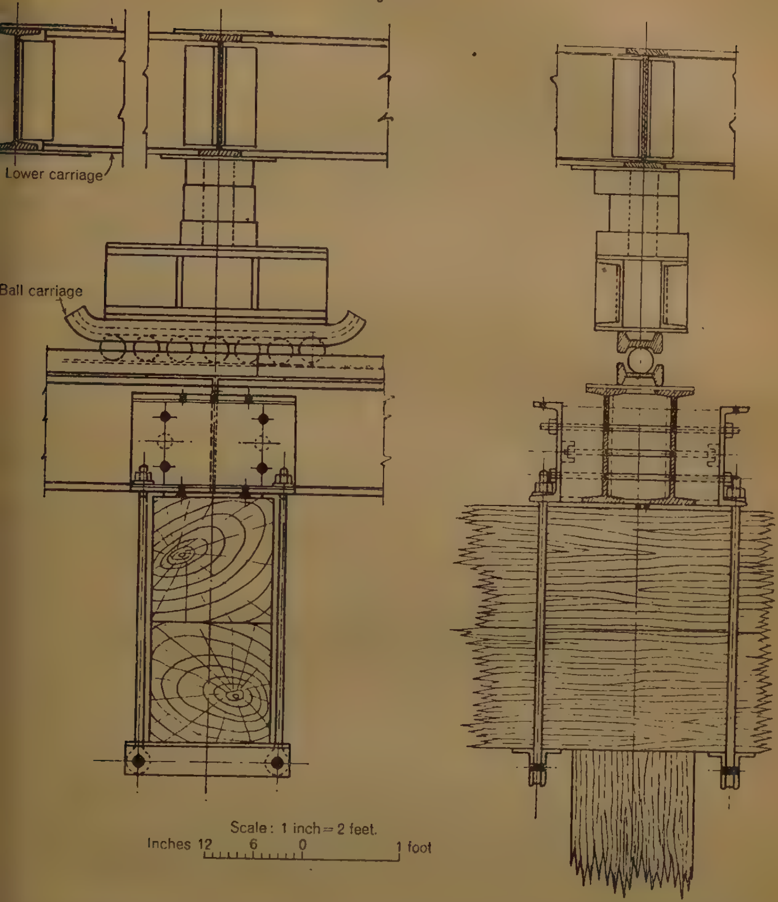


New Power-Station: General Arrangement of Plant for Constructing Timber Barge-Jetty.

runways for transporting the track beams from back to front for eac move forward of the plant.

It will be seen that the unit was so designed that the position of ever pile was accurately determined, and it may be said that for practica purposes the jetty was driven to templet.

Figs. 24.



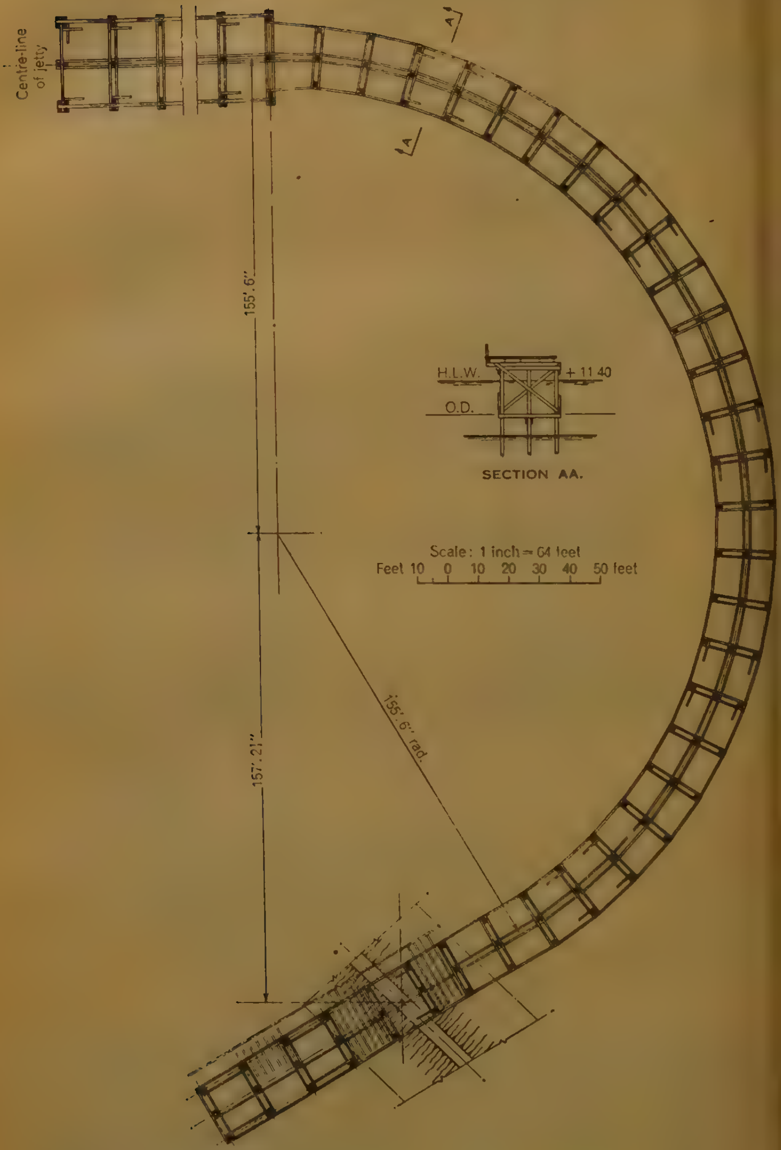
EW POWER-STATION: DETAILS OF BALL CARRIAGES FOR JETTY-CONSTRUCTION PLANT.

THE BAGHDAD BRIDGES.

The North bridge over the river Tigris in Baghdad was opened to traffic July, 1939, and the King Feisal bridge, about 1 mile downstream of the rth bridge, is under construction and should be completed early in 0. The North bridge has five spans of varying lengths, the centre n measuring 171 feet, whilst the King Feisal bridge will have seven ns, the centre span being 172 feet long.

The rise in level of the Tigris during floods reaches a maximum of about feet, and the river-bed, which is of fine silt, scours very badly during

Figs. 25.



NEW POWER-STATION: ARRANGEMENT OF TIMBER BARGE-JETTY.

ods. It was therefore decided not to pile the river-bed either for the nstruction of the piers or for the erection of the spans, as a sudden high od might readily scour around the piles and cause the collapse of any mporary stagings.

The piers sunk under compressed air were positioned, sunk, and nstructed by a floating unit carrying five derrick cranes, compressed-air ant, diesel generating plant, air-sinking equipment and concrete batcher ant.

The spans were built on shore parallel to the river, rolled out on narrow led jetties, and floated to position. It is proposed to describe the more teresting features of construction.

ier Cofferdam.

When a pier was sunk to the final level of + 30·00 the top of the caisson as at level + 80·00, whilst river-level during the working season would at anything from level + 95·00 to + 110·00. From level + 80·00 the er shaft, faced with pre-cast-concrete blocks, was built to bridge-bearing vel, a wide scarcement being provided at level + 80·00.

During the sinking of the pier caisson, and while the top of the caisson as still above water-level, a concrete curb faced on its outer edge with an gle-iron was built on the top of the caisson to receive the cofferdam. e cofferdam was of a size to fit this curb. The dam was built in sections om 5 to 8 feet wide of steel sheet-piling finished off at the bottom with a ate and projecting angle-iron. To the angle-iron on the bottom of the m a flat rubber strip 6 inches deep and about $\frac{3}{8}$ inch thick was fixed. vo steel frames were provided inside the dam, which was 22 feet deep, e at the top and the other 6 feet 3 inches below it, braced together in a rtical plane so as to be self-supporting. The dam was 15 feet 6 inches de and 60 feet long inside, and the height to the underside of the lower ame was 16 feet, thus giving within the dam an uninterrupted space for ilding the pier shaft. The dam was tied down to hairpins, projecting om the concrete in the caisson top, by wire ropes with turnbuckles. A tachable section 4 feet high was provided for use when the river-level as above + 102·00.

As sinking of the caisson proceeded and the rubber seal went below ter-level the pressure of the water on the rubber strip against the angle rb made an effective seal. When the pier had been built to above ter-level the dam was flooded, the tie-downs removed, and the dam mantled by lifting it off in sections with the pier-construction cranes. e pier caissons ranged in width from 17 feet 6 inches to 18 feet 6 inches, t the same cofferdam fitted any size of pier, as the curb was built the ne width for all piers and there was sufficient working room inside the m for the largest pier shaft. The simplicity of the joint between dam d caisson and the large working space available within the dam are the o points of particular note.

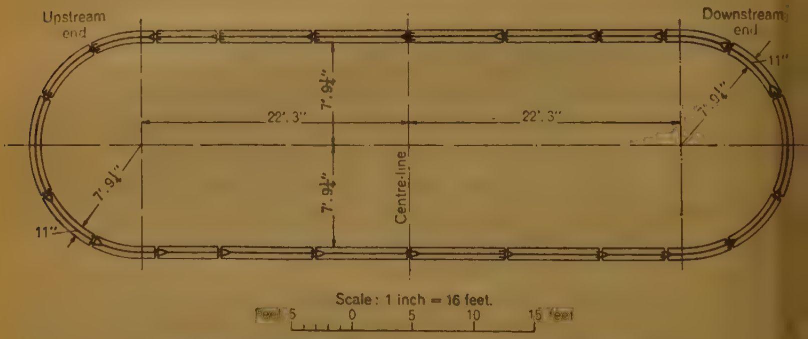
The key plan of the cofferdam is shown in *Fig. 26*, and the arrangemer and details are shown in *Figs. 27* and *28* (p. 302).

Rolling-Out the Spans.

As mentioned previously, the spans were erected on shore parallel t the river, and when complete with handrailing, lamp-standards, and othe fittings, weighed about 600 tons each.

The problem to be solved was the rolling out of this considerable weigh from its position on shore to a position over the river where the floatin units could be brought in to lift it up and float it to its final position on th piers.

Fig. 26.



BAGHDAD BRIDGES: KEY PLAN OF PIER COFFERDAM.

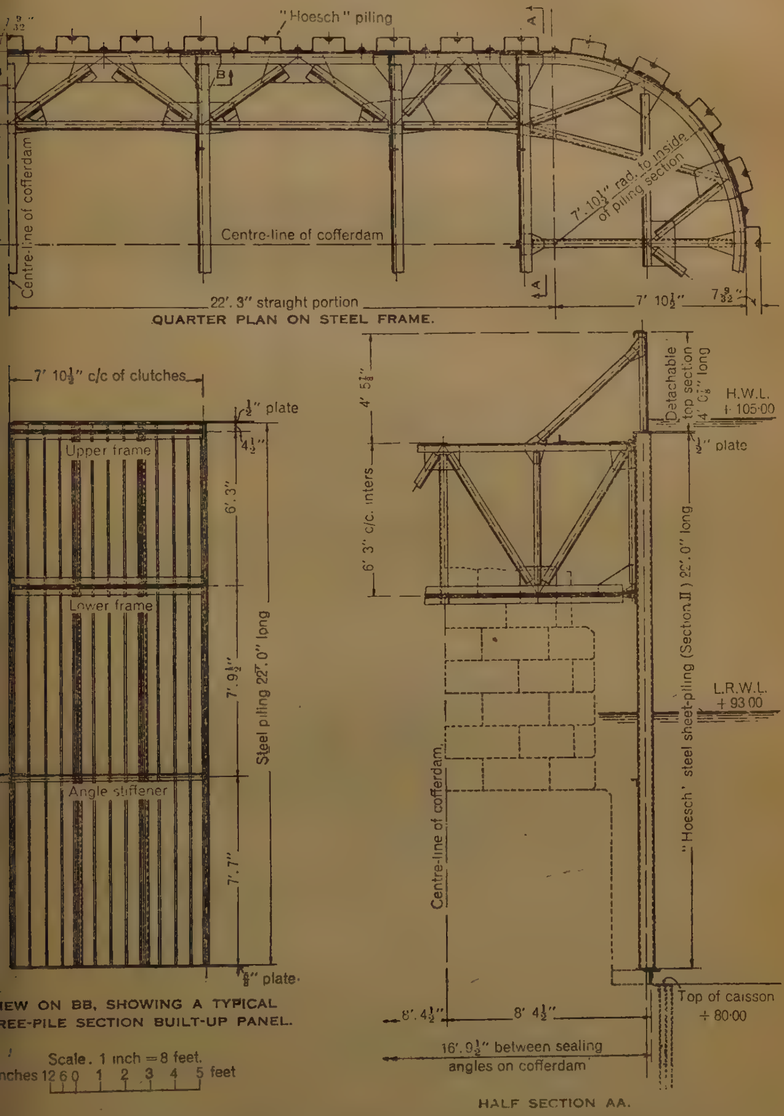
Two narrow piled jetties some 150 feet long and 152 feet 7 inches apa with steel way-beams were constructed running out into the river. O each of these way-beams, two bullheaded rails 12 inches apart and welde to a 20-inch by ½-inch steel plate were fixed to line and level, thus formin the rolling track. The carriages, four in number, were shaped rather lik sledges, the " runners ", turned up at the ends, being formed of two bul headed rails at the same cross-centres as the rolling-track rails and fixe to the underside of the carriage by a 20-inch by ½-inch steel plate, to whic the rails were welded.

The body of the carriage, about 8 feet long, was made up of two heav joists well stiffened and with diaphragms between. Between the two rai on the underside of the carriage and the two rolling-track rails on the wa beams, two lines of hard steel balls 3 inches in diameter were inserted, t balls, fifty in number, being spaced at 4-inch centres. Each ball is good f a working load of 3 tons without any sign of making a groove in the surfa of the rail.

The four carriages were then rolled under the erected span, which w jacked down on to packings on the carriages to give the correct slope the span as represented by its final position on its piers.

As with a well-laid track the friction when rolling out is less than 2 per ıt. of the weight, a hand-winch with blocks and tackle on each jetty was

Figs. 27.

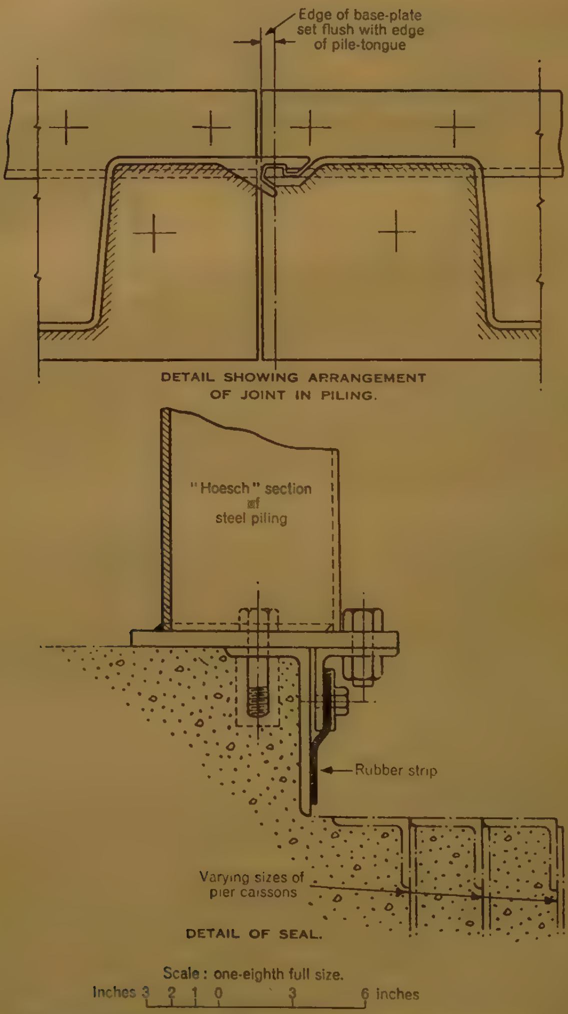


BAGHDAD BRIDGES: DETAILS OF PIER COFFERDAM.

ɔre than sufficient to pull the 600-ton load. The rate of travel is about ɔr 4 feet a minute, and two men at each carriage lift the balls one by one

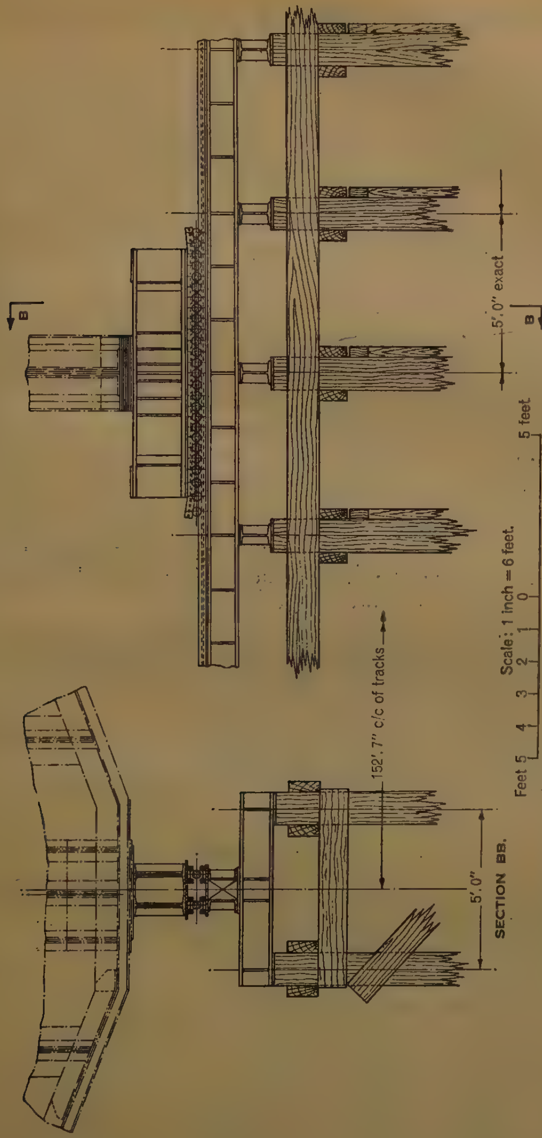
as they leave the back end of the carriage and place them on the ball trac at the forward end of the carriage, keeping the balls about 1 inch clear o each other. This is a very simple method of moving heavy concentrate

Figs. 28.



BAGHDAD BRIDGES: DETAILS OF PIER COFFERDAM.

loads over fairly short distances, and when a set of carriages are made it i surprising how often a use is found for them. The arrangement of th track is shown in Figs. 29, Plate 2, and details of the carriages are shown i *Figs. 30.*



BAGHDAD BRIDGES: DETAILS OF BALL CARRIAGES FOR ROLLING-OUT THE SPANS.

Figs. 30.

ing-Out the Spans.

here was nothing very special about the floating-out units except that, e level of the pier tops increased to the centre of the bridge and the -level varied during the floating-out season from level + 95·00 to + 108·00, it was necessary so to design the towers on the pontoons

that they could readily be adjusted in height to meet the varying co ditions.

There were two identical floating units, each consisting of a pair c pontoons 88 feet long by 20 feet wide by 8 feet deep and 5 feet apart, a joined together by two strongly-braced steel structures incorporati vertical guide-angles to accommodate the square towers supporting t span.

The towers were formed by corner angles braced on all four sides, a had horizontal diaphragms to keep them true to shape. The centres the towers corresponded to the centres of the main girders of the brid spans. Steel rubbing strips were welded within the guide-angles of t main structure, and the corner angles of the towers were made an ea sliding fit within these rubbing strips. The towers were readily raised lowered by jacks, and with holes provided in the tower angles and t guide-angles at 6-inch centres the towers could be rigidly bolted to t main structure at any desired height within a limit of 6 inches. Tv intermediate extension pieces were provided for each tower, and the n result was that the height of the towers could be set at will at any heig ranging up to 18 feet in steps of 6 inches. The top girders of the towe were arranged to take the stool brackets temporarily attached to t underside of the main girders of the bridge span.

Two units were used for floating-out a complete span with its cantilev ends, weighing up to about 600 tons, whilst one unit was used for floati out a suspended span, which weighed about 120 tons.

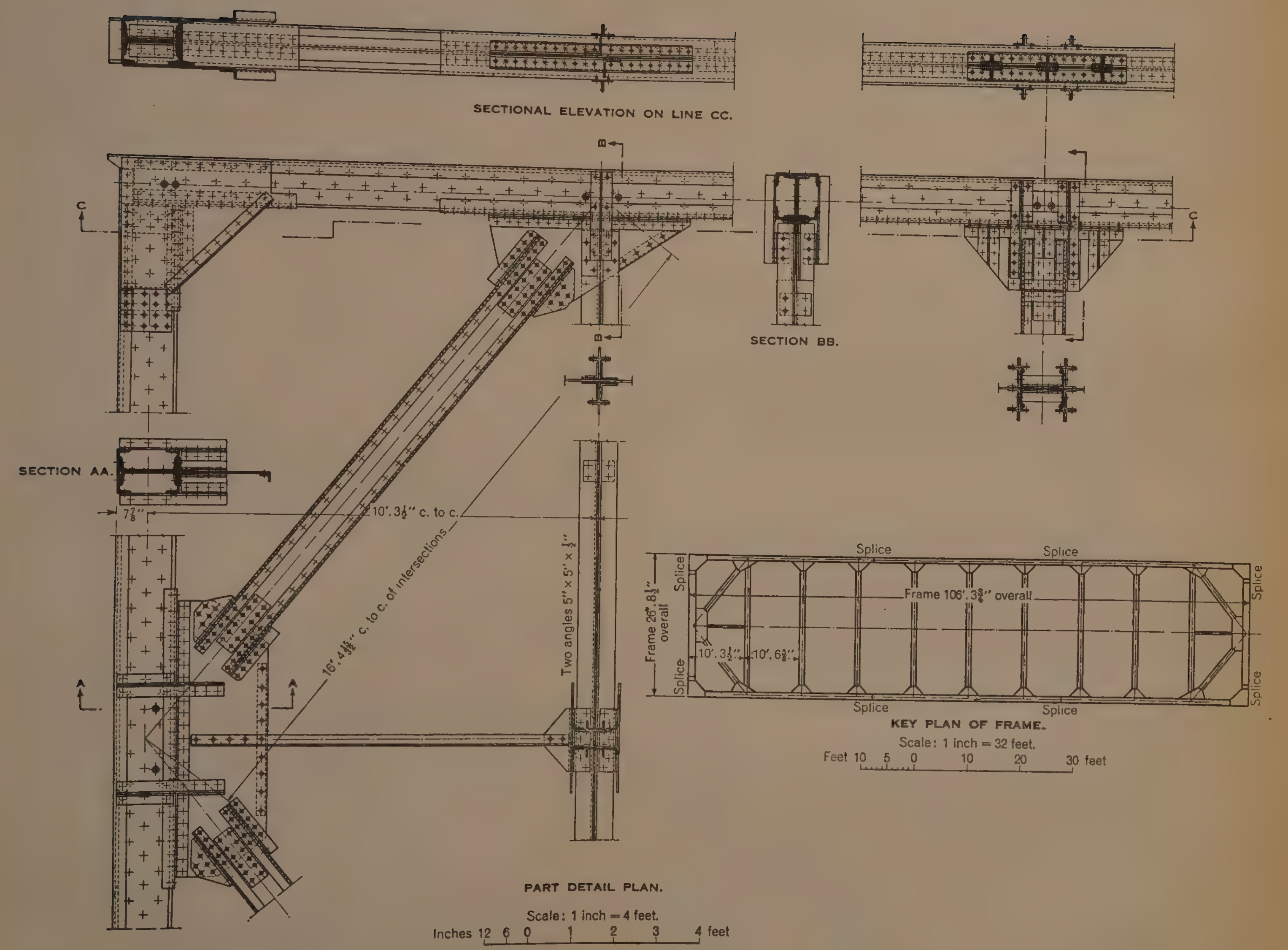
The time taken for a complete floating-out of a span, from the time t float left the rolling-out jetties until the span was landed on its piers, w from 2 to 3 hours. The arrangement is illustrated by Figs. 31, Plate 2.

CONCLUSION.

Many of the operations described in this Paper may be quite usu practice in a general way, but it is hoped that some of the methods explain may be of value to engineers and contractors should they be faced wi similar problems in the course of their work.

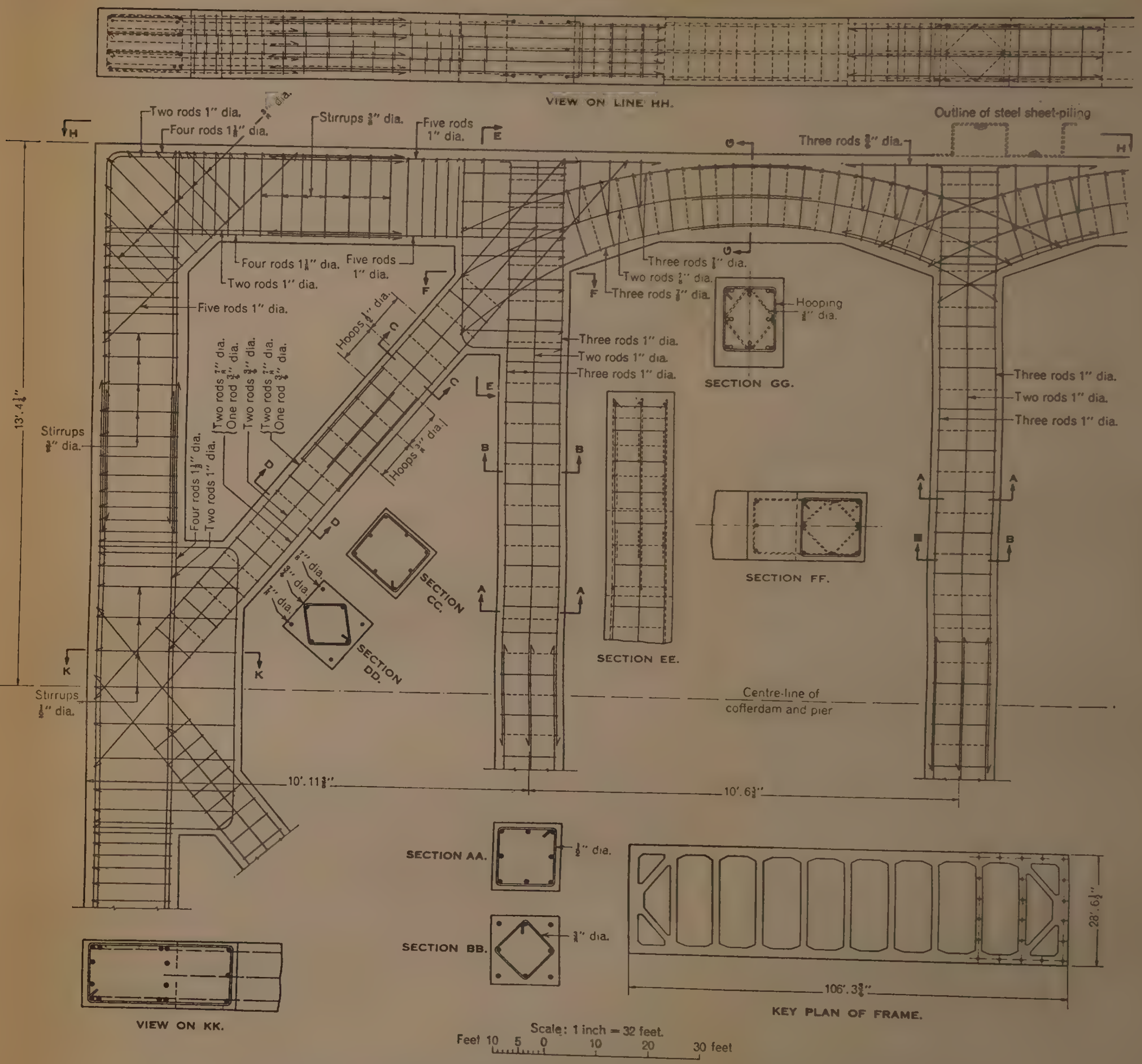
Messrs. Holloway Brothers (London), Ltd., who have carried out the works described, by giving permission to use the information and publish the various drawings, diagrams, and photographs, have made possible for this Paper to be written, and thanks are due to them, and al to Mr. F. W. Sully, Assoc. M. Inst. C.E., Mr. H. R. McHardy, B.Sc., a Mr. E. Willett, members of their staff, who have been responsible in a gre measure for the designs and the working out of the details.

Figs: 3.

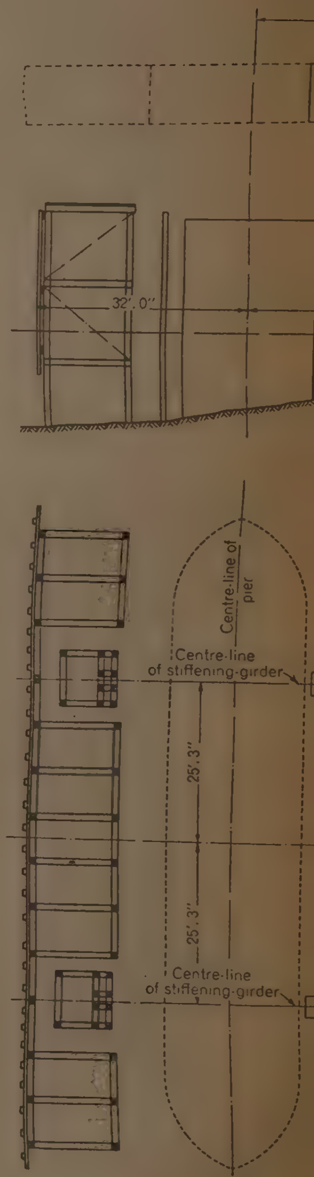


DETAILS OF FRAME B IN PIER COFFERDAM.

Figs: 4.

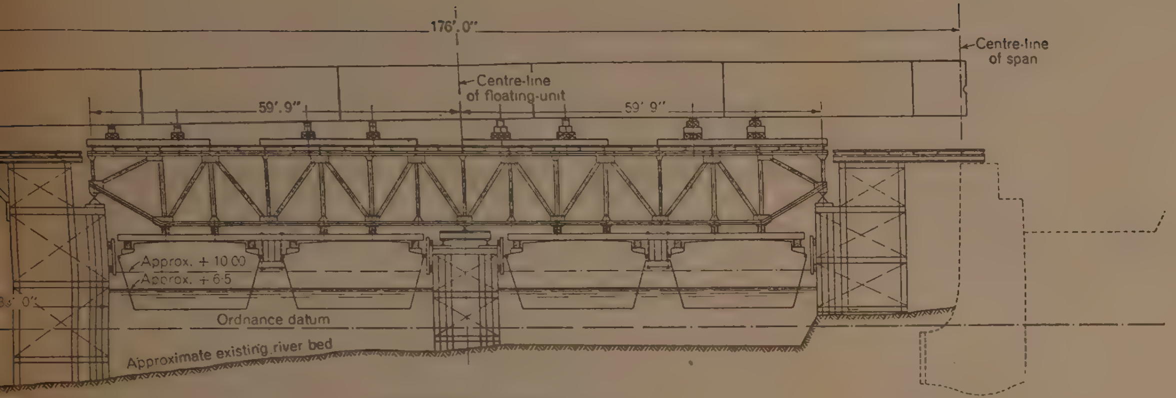


DETAILS OF REINFORCED-CONCRETE FRAME D IN PIER COFFERDAM.

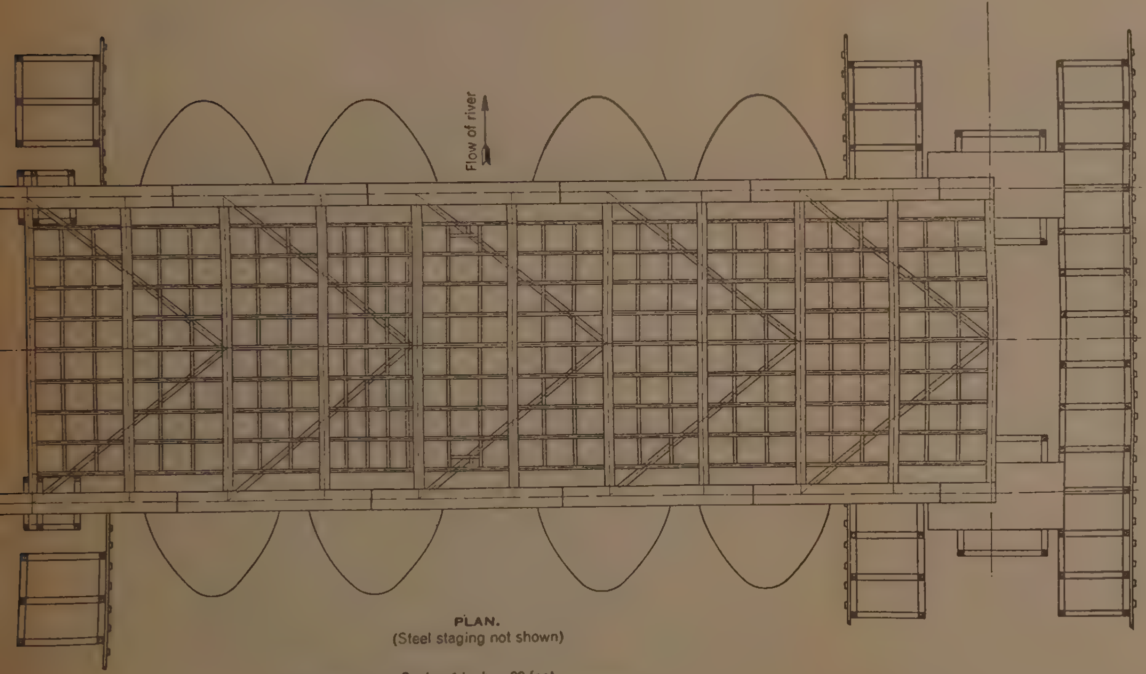


William Clowes & Sons, Limited: London.

FIGS: 9.



LONGITUDINAL SECTION.
(Showing staging supported and barges in position)

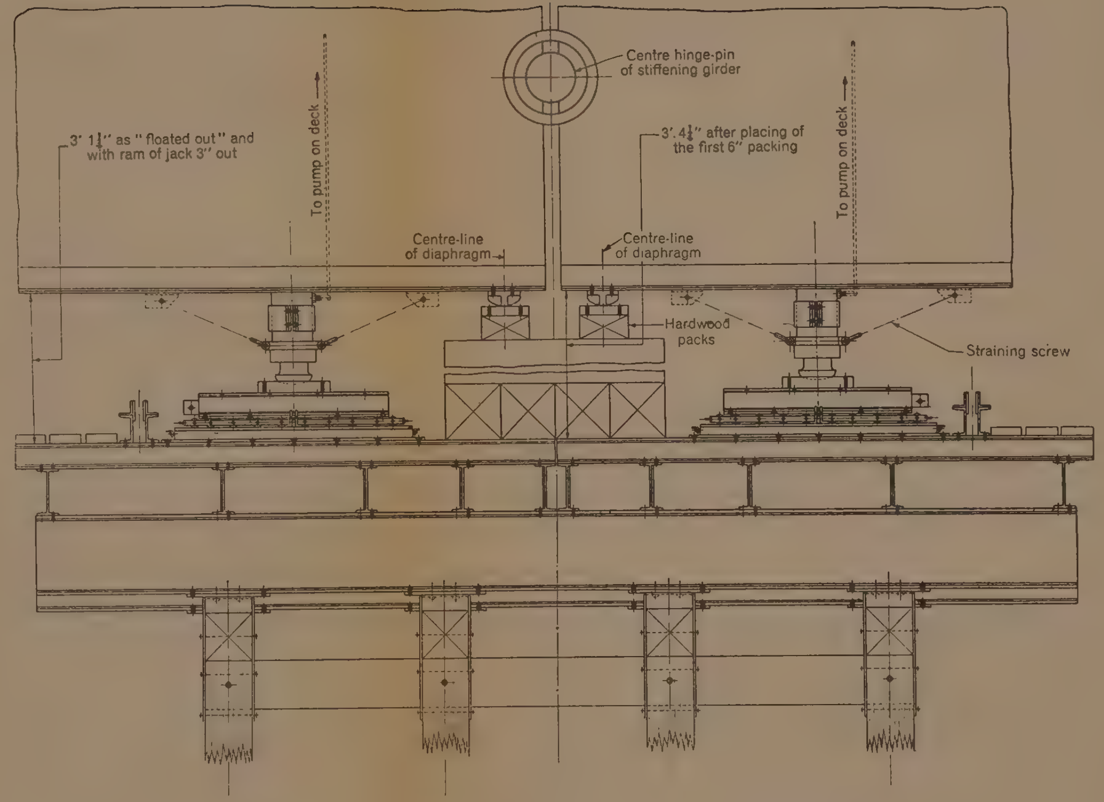


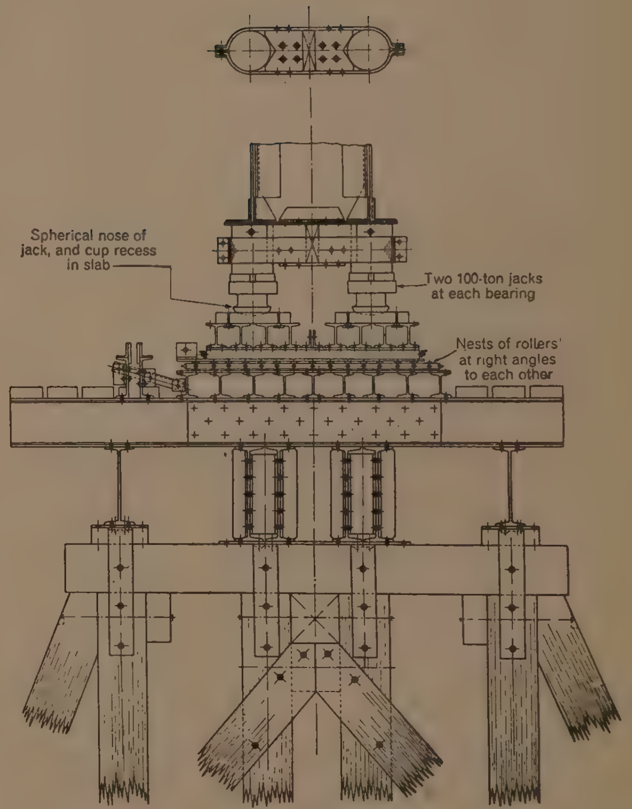
PLAN.
(Steel staging not shown)

Scale: 1 inch = 32 feet.
Feet 10 5 0 10 20 30 feet

ARRANGEMENT OF STAGING AND FLOATING PLANT.

FIGS: 10.



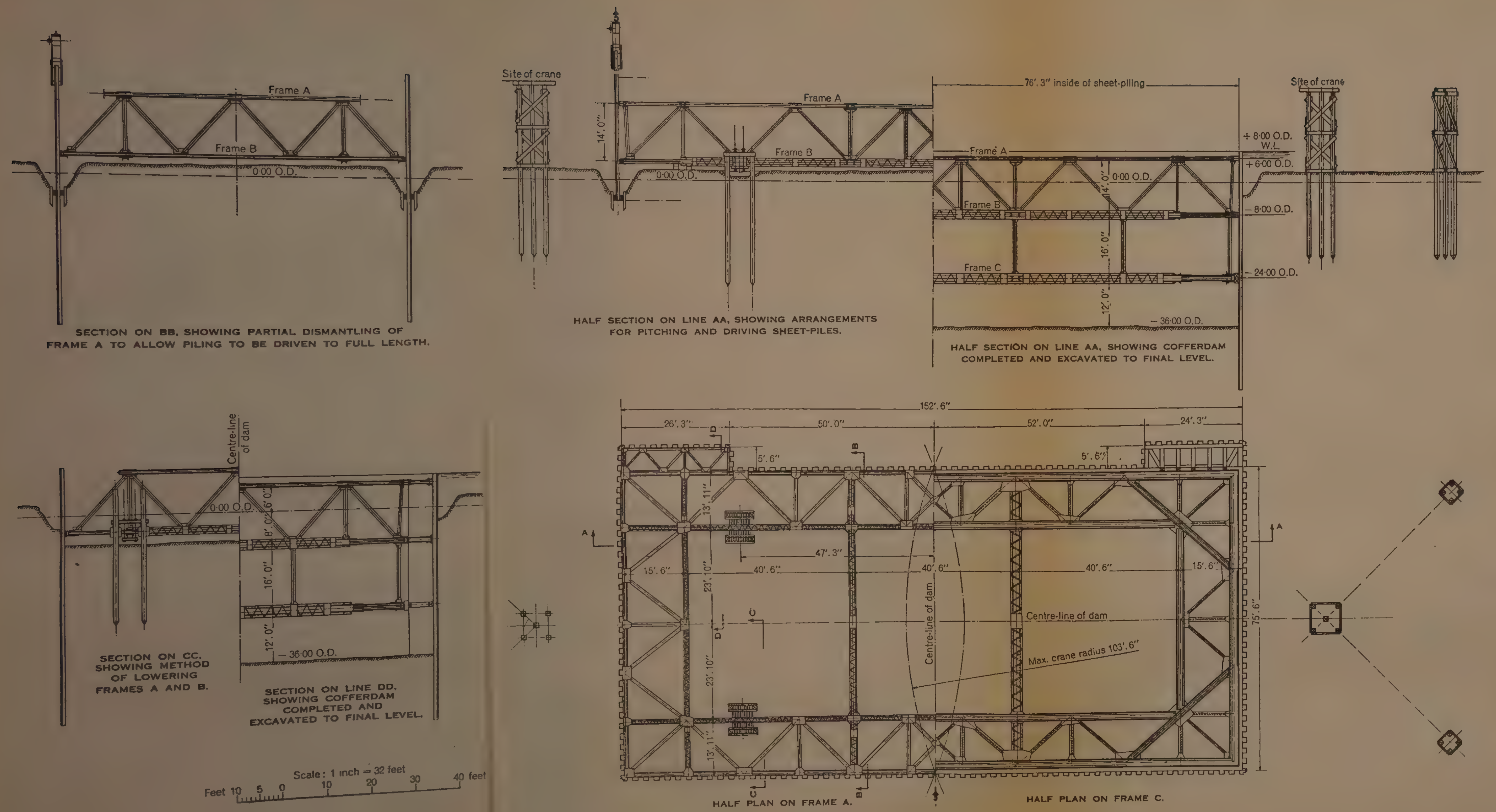


Scale. 1 inch = 4 feet.
Inches 12 6 0 1 2 3 4 feet

ARRANGEMENT OF UNIVERSAL BEARINGS AT CENTRE OF BRIDGE.

W. S. WILSON.

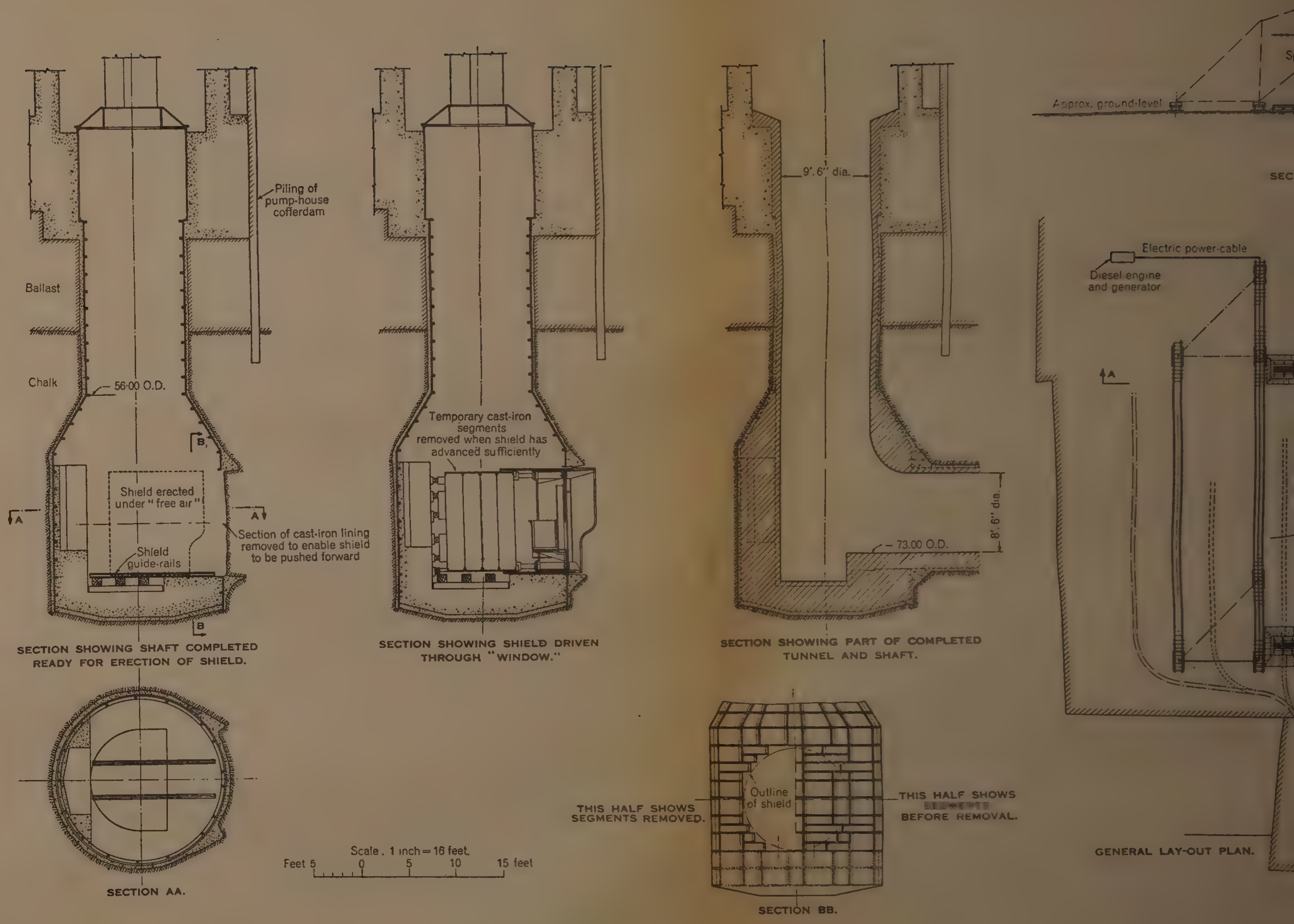
Figs: 16.



ARRANGEMENT OF PUMP-HOUSE COFFERDAM.

NEW POWER-STATION.

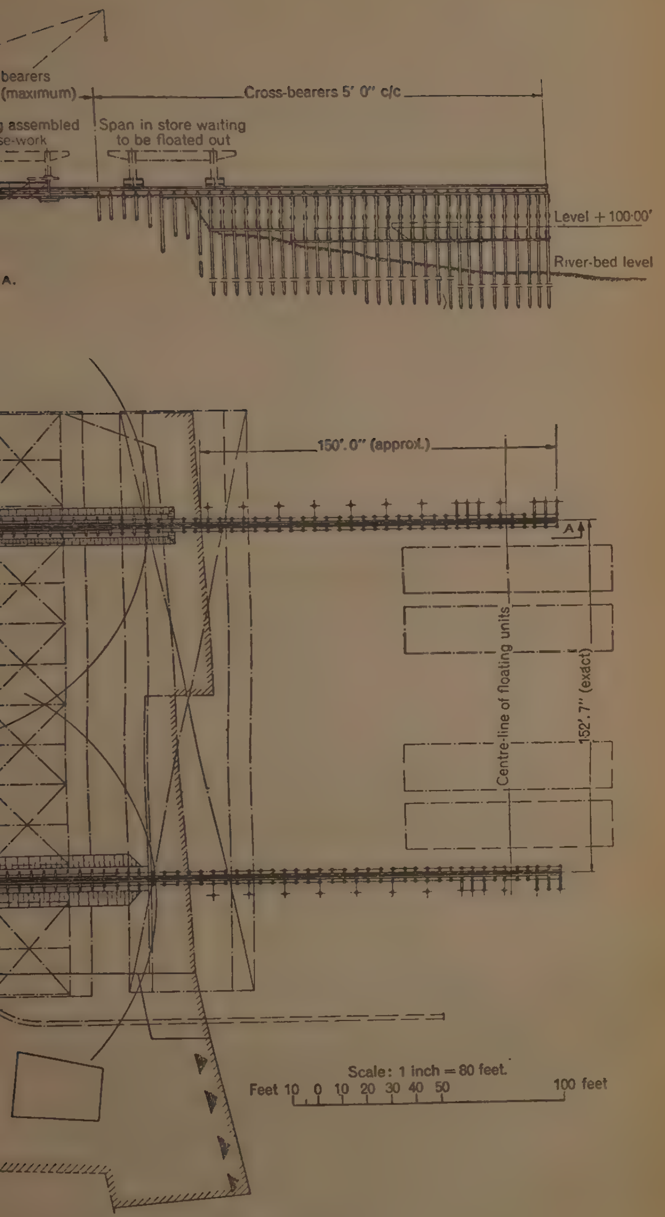
Figs: 20.



ARRANGEMENT OF SHAFT AND SHIELD-CHAMBER FOR CIRCULATING-WATER INLET-TUNNEL.

PMENT.

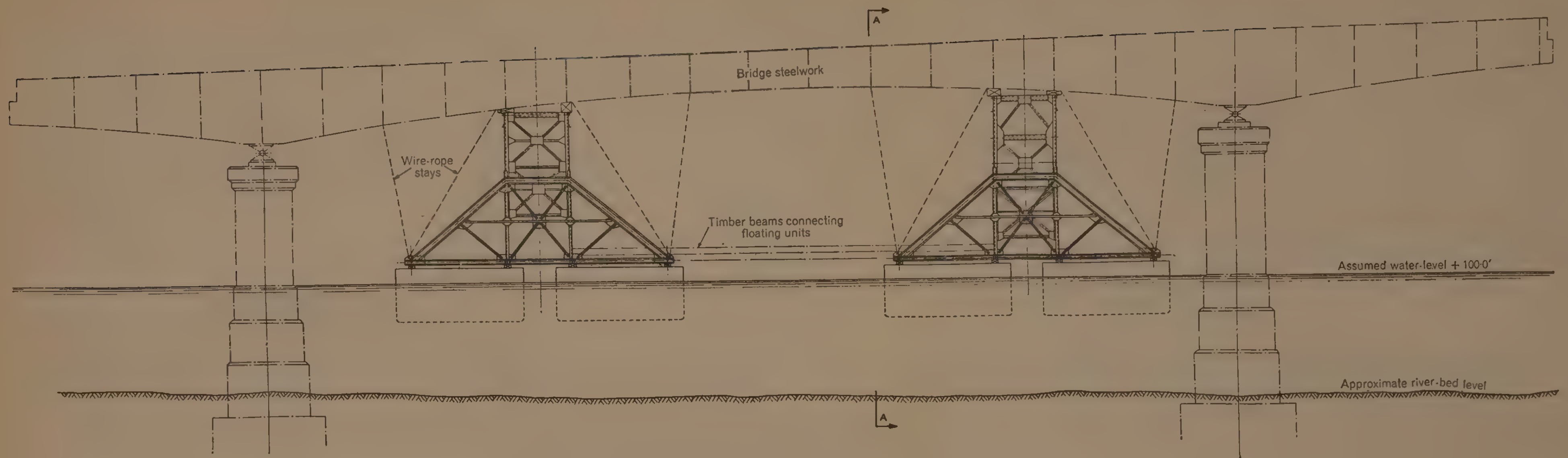
FIGS: 29.



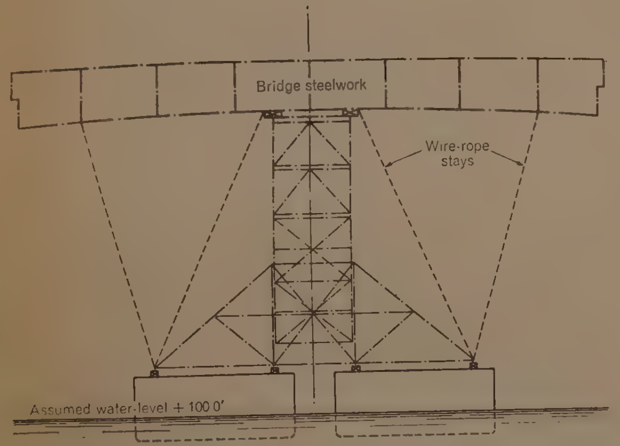
EMENT OF ROLLING-OUT JETTIES.

BAGHDAD BRIDGES.

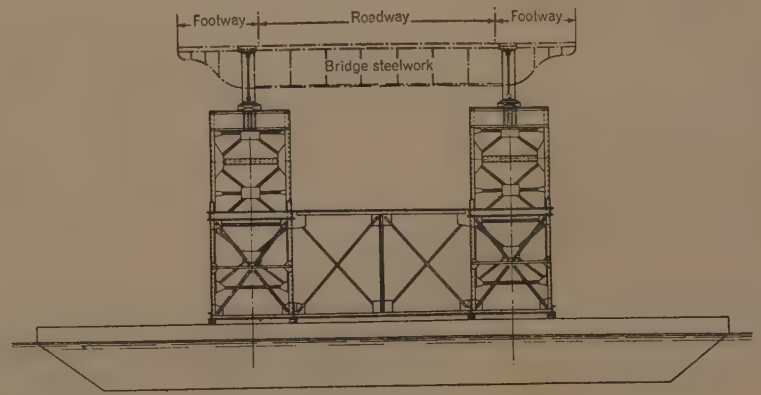
FIGS: 31.



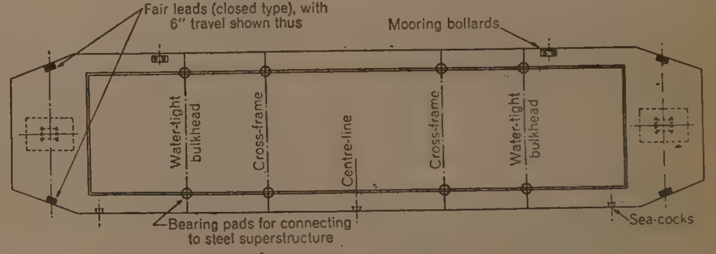
TYPICAL ARRANGEMENT FOR FLOATING OUT A LONG SPAN, USING TWO UNITS.



TYPICAL ARRANGEMENT FOR FLOATING OUT A SHORT SPAN, USING ONE UNIT.



SECTION ON AA.



PLAN OF ONE BARGE.

Scale: 1 inch = 24 feet.
Feet 10 5 0 10 20 feet

ARRANGEMENT OF STAGING FOR FLOATING OUT BRIDGE SPANS.

W. S. WILSON.

Paper No. 5224.

"Some Aspects of Aero-Hangar Design."

y Archibald Milne Hamilton, B.E., and Edgar Basil Cocks, B.E., Assoc. MM. Inst. C.E.

(Ordered by the Council to be published with written discussion [1].)

TABLE OF CONTENTS.

Introduction.

is Paper deals chiefly with the effects of wind forces on large sheds h low-pitched roofs of wide span, and with the design of the lightest sible building of this type which will be rigid and stable under all ather conditions, and yet will also possess the other desiderata of cheap- s and speed of manufacture and erection. The problem arose originally 1935, for the Directorate of Works of the Air Ministry desired to obtain h an aero-hangar to replace the Bessoneau and other light types, used ing the war of 1914–18, which were too small for modern aircraft and e, moreover, unsafe in severe storms.

At the Authors' suggestion the problem was approached by first aining a wind-tunnel-test report from the National Physical Labora- y. Experiments were made there to ascertain the distribution of wind es over a scale model of a hangar of the required size and shape. This er is intended to indicate the Authors' interpretation of the results

[1] Correspondence on this Paper can be accepted until the 15th June, 1940, and be published in the Institution Journal for October, 1940.—Sec. Inst. C.E.

of those experiments with regard to structural design. The Directorat of Works indicated that the hangar should have internal dimensions c not less than 175 feet by 90 feet, a roof slope not steeper than 1 in 8, an a clear door height of at least 25 feet. The model used by the Nationa Physical Laboratory was constructed of wood to a scale of $\frac{1}{8}$ inch to 1 foo The pressures over the surfaces were measured by means of a syster of manometer tubes terminating in small holes which opened flush wit the walls or roof, and which did not impede the wind stream in an way.

Quite apart from their usefulness for design purposes, the results c these wind-experiments are in themselves particularly interesting, fo some of the common engineering rules of wind-pressures and suctions— such, for example, as "there must always exist a pressure on a windwar roof slope and a suction on the leeward slope"—are shown by the exper ments to be incorrect for low slopes. Also, the commonly-used Duchemi formula, $N = P\frac{2 \sin \theta}{1 + \sin^2\theta}$, (where N denotes the normal pressure on a roo P the horizontal pressure on a vertical plate, and θ the inclination of th roof in degrees) certainly does not apply to 5-degree slopes.

Whatever may be the case for steeply pitched roofs, it would seem t be generally true to say that for slopes of 1 in 10 (the slope eventuall adopted by the Authors) there is, normally, suction over the entire roo irrespective of the direction of the wind. Moreover, the suction pressur rise to higher peak values and have a considerably greater overall effe on the correct design of the hangar than have the wall pressures.

It is seen from the results of the model-test that the maximum suctio occurs on the windward slope of the roof and not on the leeward slope as migl have been expected. As an example of the inaccuracy of the Duchem formula, the pressure on the windward slope produced by a wind exertin a wall pressure of 20 lb. per square foot is calculated, by that formula, to l $3\frac{1}{2}$ lb. per square foot positive, whereas the model-tests indicate that the would be a maximum suction of about 30 lb. per square foot. The failu of sheds in hurricanes has, in fact, generally been due to uplift and t tearing off of the roof covering; only wind-tunnel experiments can gi the full explanation of this phenomenon. Thus the correct procedure designing such large buildings, with due regard to wind-pressure, is to u the wind-tunnel distribution pressures measured on the model and bas on the highest velocities which are ever likely to arise in the locality which the shed is to be erected. Wind-tunnel experiments are not e pensive, and it is the Authors' opinion that, for all such light buildin and structures, they are almost indispensable to proper design.

The conversion of wind-tunnel results to full-scale effects in the fie is, fortunately, a very easy one. "Scale-effect", which is concerned wi the influence of the Reynolds number $\frac{vl}{\nu}$ in the expression:

$$p = \rho v^2 f \frac{(vl)}{\nu} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where p denotes the pressure intensity at any point,
ρ „ the density of the air,
v „ the velocity of the wind stream,
l „ a linear dimension,
ν „ the kinematic viscosity of the air,
nd f represents an experimentally determined function) is a compara-ively small one, and it is sufficiently accurate to consider $f\frac{(vl)}{\nu}$ to be a con-tant for the range of dimensions under consideration. Then, all pressures er square foot, on whatever part of the shed, vary as the square of the ind velocity only. (The conversion would not be so simple in the case f curved roofs.) It follows that the alteration of a design to suit a hange in wind velocity (if prescribed by locality or other circumstances) s then a very simple matter[1].

The hangar under consideration is composed of latticed ribs of square ox form, spanning the complete width of the hangar, and joined by urlins on which the outside sheeting is fixed. The ribs consist of two ertical legs joined by the sloping roof sections, the whole forming a con-inuous framework. The bottoms of the verticals are fixed to grillages of leepers, or concrete slabs, located below ground-level so that, in firm oundations, the rib may form a portal frame with fixed ends. Such lattice ibs result in what is believed to be about the lightest form of construction or a shed of the given dimensions.

Much attention has been paid by the Authors to the theoretical in-estigation of the "hingeless" portal frame under the action of horizontal nd vertical forces. Although the ribs are not without thickness, as the athematical theory assumes, nevertheless, the analysis and the derived ormulas are considered to be sufficiently reliable for design purposes. he Authors have made the utmost endeavour to present the results of eir work in such form that they can easily be used by others, and, to the est of their knowledge, the solution of the hingeless portal has not been completely set out before.

It might be wise, at this juncture, to comment on the "geodetic" ature of the lattice framework used to form the sides of the box ribs nployed in the design. The term "geodetic" has, for some reason, ome to be applied to a certain form of aeroplane fuselage and wing construc-on where all members are continuous and intersecting, the object being to duce the unsupported lengths of all compression flanges or compression embers, and to produce greater rigidity and strength with less weight. his "geodetic" principle of construction is employed in the design of

[1] "Wind-Pressures on Latticed Towers—Tests on Models." British Electrical d Allied Industries Research Association, Report F/T 84, 1935.

the hangar rib, in so far as all web compression members are supported a mid-length by the intersecting web tension members; the design lengt of the struts is thereby halved.

Mr. C. O. Boyse and Mr. G. D. White-Parsons of Callender's Cable an Construction Company, Ltd., were responsible for the final design of th hangar rib on this system, which is the same as that used in the construc tion of the now familiar transmission towers carrying high-tensio conductors throughout the country. The actual strength of this lattice web system has frequently been determined by full-scale tests to destruc tion on towers with just such a form of bracing, and so the safe allowabl stress values are accurately known.

Particularly interesting are the investigations of the two limitin "emergency conditions" of wind load, assuming combinations of violen winds and some resulting damage to the covering. These investigation the Authors believe, throw a new light on the way in which building actually fail in hurricanes. It will be seen that the extent and positio of local damage may completely alter the main pressure distribution generally for the worse as far as stability is concerned. The effect is b no means simple and is complicated by the unknown period of duratio of maximum pressure and many other factors.

Wind-Pressure Design.

The results of the wind-tunnel test on the model, as supplied by th National Physical Laboratory, are in the form of tabulated coefficient ("C") in the following equation:

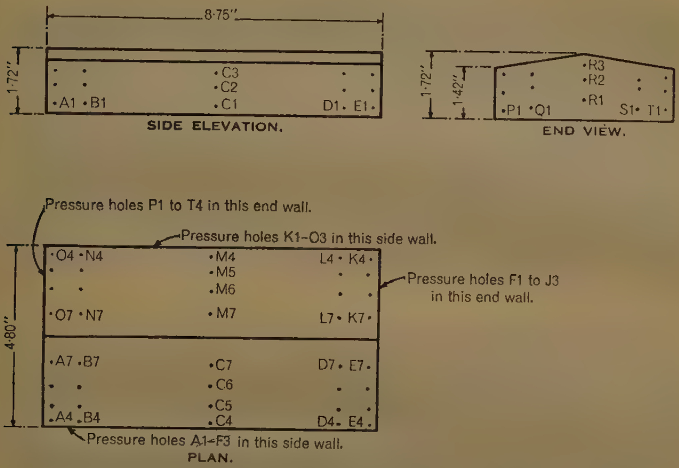
$$p - p_0 = C \cdot \frac{\rho v^2}{2g} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where p_0 is some datum pressure (in this case, the pressure measured at small hole in the wall of the wind tunnel). It will be shown later that thi datum pressure is an important value.

At any given cross-section of the hangar—longitudinal or transverse— the pressure resultants, $p - p_0$, at all points on or near the section ma be plotted, and, on making the rather arbitrary assumption that p_0 is als the pressure of the still air within the model (or within the hangar), then th curve represents the net wind load on the covering. (It will be show that the pressures within the hangar may vary within certain limits, an the curves for extreme possible pressures will be referred to later in th Paper.) To give a general picture of the distribution of pressure over th whole of the model (*Figs. 1*), the coefficients themselves are plotted o the developed surfaces as shown in *Figs. 2* (p. 310). The National Physica Laboratory has confirmed, by very complete observations on an actua hangar in the field during strong winds, that these pressure distribution actually do exist and are substantially in agreement with the result

f the model-tests. The approximate variation of the velocity of the wind ith the height above the ground-level, as indicated by a wind-tunnel st, is shown in *Fig. 3* (p. 311). The field observations have shown, owever, that there may be considerable momentary divergences from

Figs. 1.

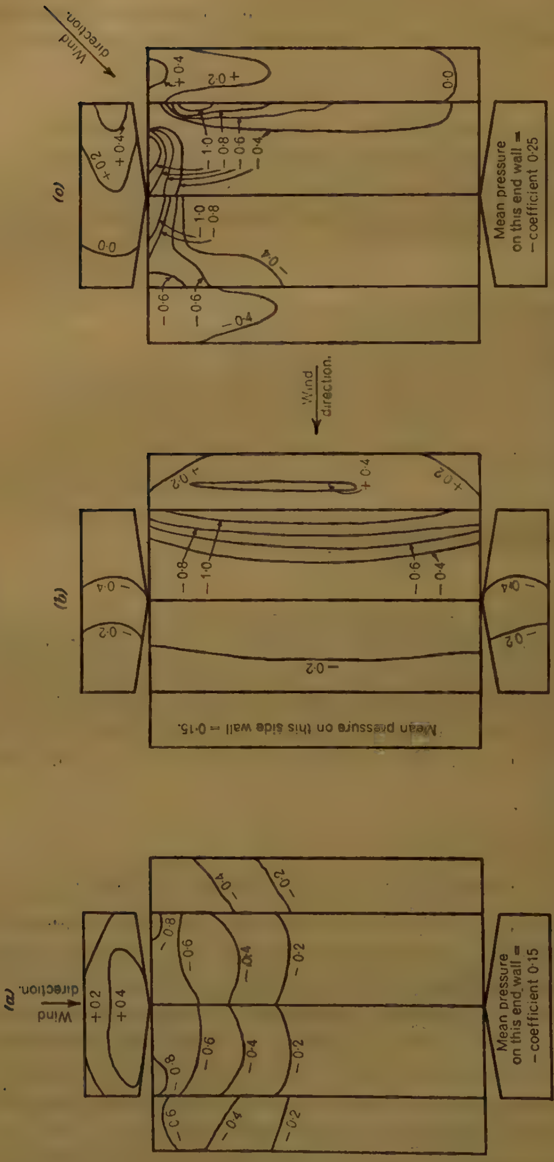


ch a curve, even in apparently steady winds. *Fig. 4* (p. 312) shows, agrammatically, the Authors' opinion of what may occur when a wind deflected by a hangar. *Figs. 5, 6*, and *7* (facing pp. 310 and 311), ich are recent photographs obtained from model-tests, using water, ow, perhaps more clearly, what may be taking place, even though the eynolds numbers for the models used and for the actual hangars were ry different.

Maximum Winds for Design Purposes.

To specify the maximum wind velocity to be used in design is generally e most difficult problem of all. Table I (p. 311) is reproduced from ent's Mechanical Engineers Handbook and is a summary of wind velocities d their common meanings. Whether the hangar should be designed for ' great storm" (70 miles per hour), a "hurricane" (80 miles per hour), "immense hurricane" (100 miles per hour), or freak storms and nadoes of even greater velocity and destructiveness, is a question upon ich only experience of the locality can decide.

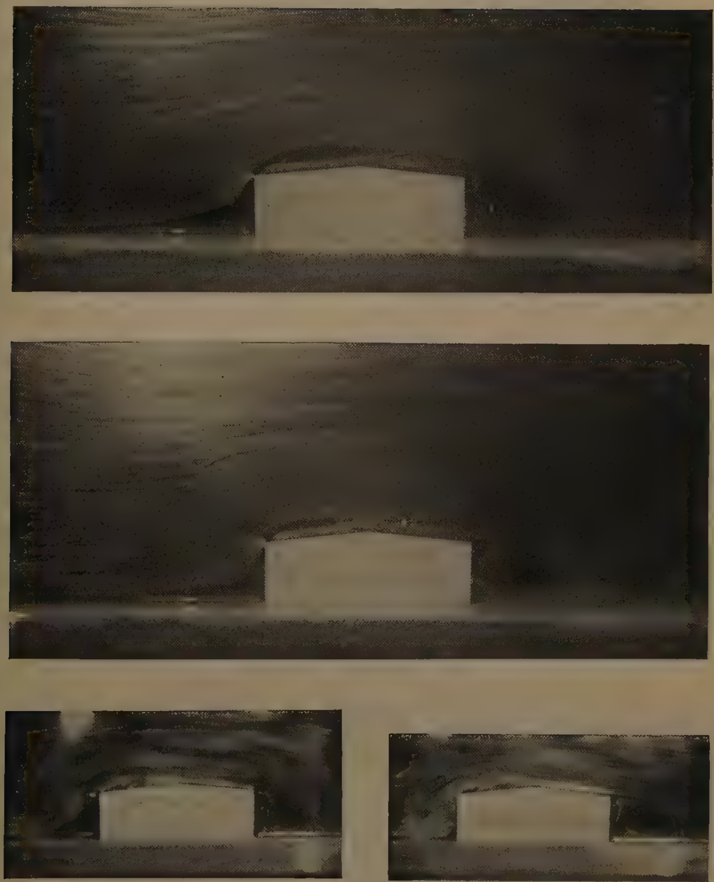
Such considerations make it extremely interesting to know that the ngar under review was designed with a factor of safety of $1\frac{1}{2}$ on the urricane" (80 miles per hour) basis, and all the hangars now in service e withstood exceptionally severe winds, on some aerodromes, closely



Figs. 2.

VARIATION OF THE COEFFICIENT "C" IN EQUATION (2) FOR DIFFERENT WIND DIRECTIONS.

Figs. 5.



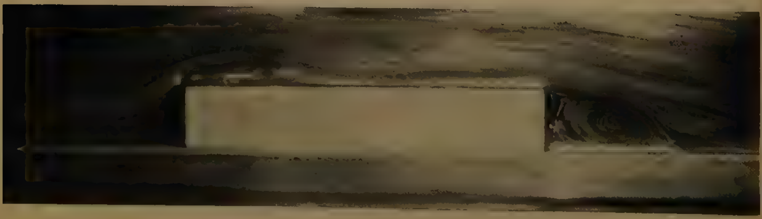
MODEL-EXPERIMENTS SHOWING EDDY CURRENTS ON THE LEE SIDE AND TURBULENCE ON THE ROOF FOR VARIOUS VELOCITIES.

5224.

Fig. 6.

FURTHER MODEL-EXPERIMENTS SHOWING EDDY CURRENTS ON THE LEE SIDE AND TURBULENCE ON THE WINDWARD ROOF SLOPE.

Figs. 7.



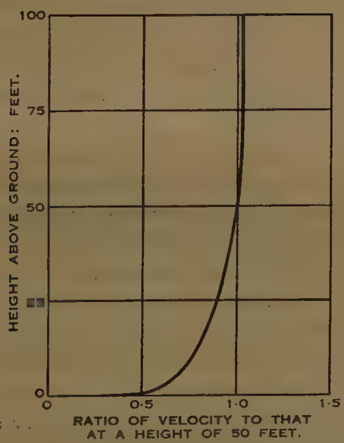
MODEL-EXPERIMENTS SHOWING TURBULENCE AND EDDIES WHEN THE FLOW IS IN A LONGITUDINAL DIRECTION.

TABLE I.—VELOCITY OF THE WIND (SMEATON).

Wind velocity: Miles per hour.	Wind velocity: Feet per second.	Common appellation of the force of the wind.	Wind velocity: Miles per hour.	Wind velocity: Feet per second.	Common appellation of the force of the wind.
1	1·47	Hardly perceptible.	18	26·40	
2	2·93	Just perceptible.	20	29·34	Very brisk.
3	4·40		25	36·67	
4	5·87		30	44·00	High wind.
5	7·33		35	51·34	
6	8·80	Gentle pleasant wind.	40	58·68	
7	10·25		45	66·01	
8	11·75		50	73·35	Very high storm.
9	13·20		55	80·70	
10	14·67		60	88·00	
12	17·60	Pleasant brisk gale.	65	95·30	Great storm.
14	20·50		70	102·50	
15	22·00		75	110·00	Hurricane.
16	23·45		80	117·36	
			100	146·67	Immense hurricane.

pproaching that velocity during the past 3 years, and have suffered no amage.

Fig. 3.

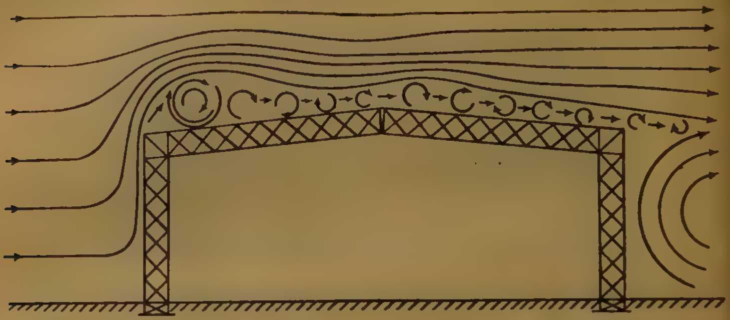


THE PORTAL FRAME.

The Authors have carefully considered whether the most suitable type f portal frame should be fixed-ended or hinged-ended, whether it should ave a top central hinge as frequently seen in large railway-station buildgs, or, alternatively, whether it should be a simple roof truss on well

braced walls. After due consideration of the stresses concerned and th lightness of construction demanded, it was decided that the most suitabl

Fig. 4.



type to adopt was the two-hinged or hingeless portal frame, since that typ gave the greatest covered area with but little excess structure above an around the net enclosed space required.

STANDARDIZATION.

The next step in the design is considered to be a very important one It was decided that the rib should be of standard section throughout, an should nominally have "fixed ends." With foundations set in yieldin soil the ends may tend to be "hinged" rather than "fixed", but thi will be shown to have little effect on the determination of the standar size of section that is necessary.

Compared with the design of a rib of varying depth and strength, o one with tapering legs, the adoption of a standard cross-section, based i strength on the maximum bending moment and shear forces that aris anywhere in the rib, enables the rib components to be reduced to a fe standard parts, and simplifies the calculations. Moreover, when all th possible conditions of loading are taken into account, such a standardize rib meets the bending moment and shear requirements quite economically Furthermore, a standardized cross-section allows the hangar to be varie in height or in span within certain limits. Thus in the analysis a clea height of 30 feet has been allowed for, giving a maximum eaves height o 35 feet, this being the greatest probable height of any hangar, althoug with modern low-winged aircraft, a door height of 20 feet is sufficient fo many classes of machines.

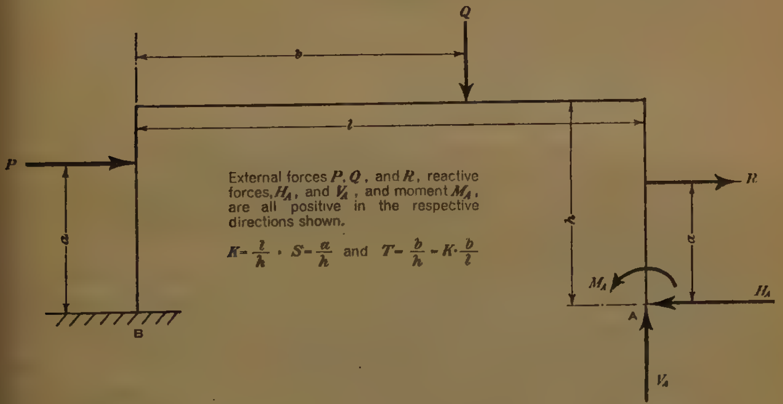
The advantages, both in manufacture and erection, of these fixed-ende ribs of standard parts are substantial. Also, for a Service structure liabl to damage by bombing, a lattice fixed-ended rib is very secure and stabl and, even if a large number of the members should be cut or bent b splinters or blast effects, there are, in such a "geodetic" lattice structur

lmost twice as many members as are needed for the simple triangulation f the framework, so that there is virtually a double chance that the hangar ill remain standing. Moreover, repair of damage, when necessary, is, ith these bolted lattice frames, a very simple matter, for the damaged art is just unbolted and a new part is bolted in. The parts are all so light weight that they can be lifted and carried up within the rib itself by one r two men ; there is generally no need for falsework or temporary propping f the roof during a part replacement. Unless there has been injury to everal adjacent complementary members the rib is not likely even to have agged out of shape. If the damage necessitates complete dismantling f the rib, the procedure is quite simple.

Analysis of the Portal Frame.

Portal-frame analysis has consisted chiefly in the plotting of influence nes for the horizontal and vertical end-reactions (and also for the bending noments in the case of the fixed-ended rib) from the equations. Although he reactions for vertical forces on a continuous frame of this kind are given many textbooks, no published formulas for single horizontal forces cting on the vertical limbs could be found. The Authors therefore derived heir own solutions for the reactions produced by such forces.

Fig. 8.



The well-known reaction equations have, for simplicity, been derived or a flat-topped portal (*Fig. 8*) instead of for a portal with a 1 in 10 rise. These equations for a hangar rib with fixed ends are :—

$$\Sigma H_A = \overset{0\to h}{\Sigma} H_A(P) + \overset{0\to l}{\Sigma} H_A(Q) + \overset{0\to h}{\Sigma} H_A(R),$$

$$\Sigma V_A = \overset{0\to h}{\Sigma} V_A(P) + \overset{0\to l}{\Sigma} V_A(Q) + \overset{0\to h}{\Sigma} V_A(R),$$

nd

$$\Sigma M_A = \overset{0\to h}{\Sigma} M_A(P) + \overset{0\to l}{\Sigma} M_A(Q) + \overset{0\to h}{\Sigma} M_A(R),$$

since :

for force P, a varies from 0 to h (or S varies from 0 to 1),
for force Q, b varies from 0 to l (or T varies from 0 to K),
and for force R, a varies from 0 to h (or S varies from 0 to 1).

The general equations for all cases may be tabulated in the following way :—

Hangar Rib with Fixed Ends.

For P (*Horizontal force on vertical limb at* B).

$$H_A = PS^2\left\{\frac{3(1+K) - S(2+K)}{2(1+2K)}\right\}$$

$$V_A = PS^2\left\{\frac{3}{K(6+K)}\right\}$$

$$M_A = PS^2h\left\{\frac{(9+14K+3K^2) - S(1+K)(6+K)}{2(6+K)(1+2K)}\right\}$$

$$H_B = P - H_A$$
$$V_B = -V_A$$
$$M_B = M_A + h(V_AK - PS)$$

For Q (*Vertical force on horizontal limb*).

$$H_A = QT\left\{\frac{3(K-T)}{2(1+2K)}\right\}$$

$$V_A = QT\left\{\frac{6K+3KT-2T^2}{K^2(6+K)}\right\}$$

$$M_A = QTh\left\{\frac{(K-T)(3K^2+7K-4KT-2T)}{2K(1+2K)(6+K)}\right\}$$

$$H_B = -H_A$$
$$V_B = Q - V_A$$
$$M_B = M_A + h(V_AK - QT)$$

For R (*horizontal force on vertical limb at* A).

$$H_A = R\left\{1 + \frac{S^2[S(2+K) - 3(1+K)]}{2(1+2K)}\right\}$$

$$V_A = R\left\{\frac{3S^2}{K(6+K)}\right\}$$

$$M_A = RhS\left\{1 - \frac{3S}{(6+K)} - S\left[\frac{(9+14K+3K^2) - S(1+K)(6+K)}{2(6+K)(1+2K)}\right]\right\}$$

$$H_B = R - H_A$$
$$V_B = -V_A$$
$$M_B = M_A + h(V_AK - RS)$$

angar Rib with Hinged Ends.

For P (horizontal force on vertical limb at B).

$$H_A = \frac{PS}{2}\left\{\frac{3K + 3 - S^2}{2 + 3K}\right\}$$

$$V_A = \frac{PS}{K}$$

$$H_B = P - H_A$$

$$V_B = -V_A$$

$$M_A = M_B = 0$$

For Q (vertical force on horizontal limb).

$$H_A = \frac{3QT(K - T)}{2(2 + 3K)}$$

$$V_A = \frac{QT}{K}$$

$$H_B = -H_A$$

$$V_B = Q - V_A$$

$$M_A = M_B = 0$$

For R (horizontal force on vertical limb at A).

$$H_A = R\left\{1 - \frac{S}{2}\left[\frac{3K + 3 - S^2}{2 + 3K}\right]\right\}$$

$$V_A = \frac{RS}{K}$$

$$H_B = \frac{RS}{2}\left\{\frac{3K + 3 - S^2}{2 + 3K}\right\}$$

$$V_B = -V_A$$

$$M_A = M_B = 0$$

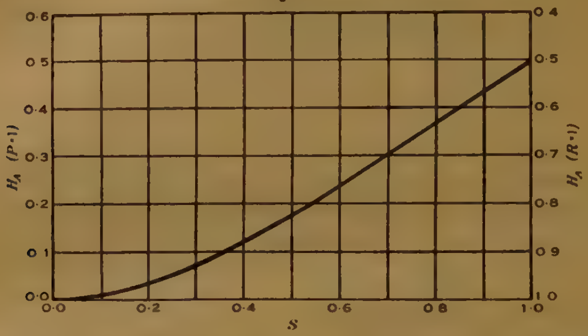
he Authors hope that these new equations may prove to be useful in the lculation of fixed-ended reinforced-concrete frames with side forces.

The use of the influence lines derived from these equations for single rces only (*Figs. 9* to *14*, pp. 316 *et seq.*), was preferred by the Authors the making of direct solutions to complete systems of forces, either from st principles or by the admirable Hardy Cross method. By simple ithmetical summations these influence lines may be used for estimating e resultants of any system of forces whatever, in all frames within the ight-to-span ratios (2 to 3·5) which have been plotted in *Figs. 9* to *14.* should be pointed out that *Figs. 9* to *14* refer to fixed-end conditions.

As the assumed flat-topped portal has been taken as a "mean" of the tual frame dimensions, the error in the disposition of the reactions between e two ends is very small. Having obtained the total reactions from e summation of the reactions for the individual forces, the bending

moments throughout the frame are then based on the *actual* shape c
the frame.

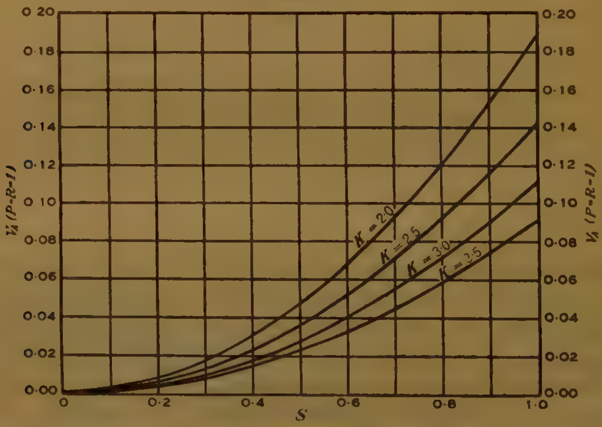
Fig. 9.



The effects of temperature also may be questioned. Some temperatur
stresses may, and undoubtedly do, exist; but in such a bolted structur
with hole clearances allowing up to $\frac{1}{16}$ inch movement at each joint, anc
having a general shape which lends itself to the relief of temperature
stresses, the effects are quite secondary.

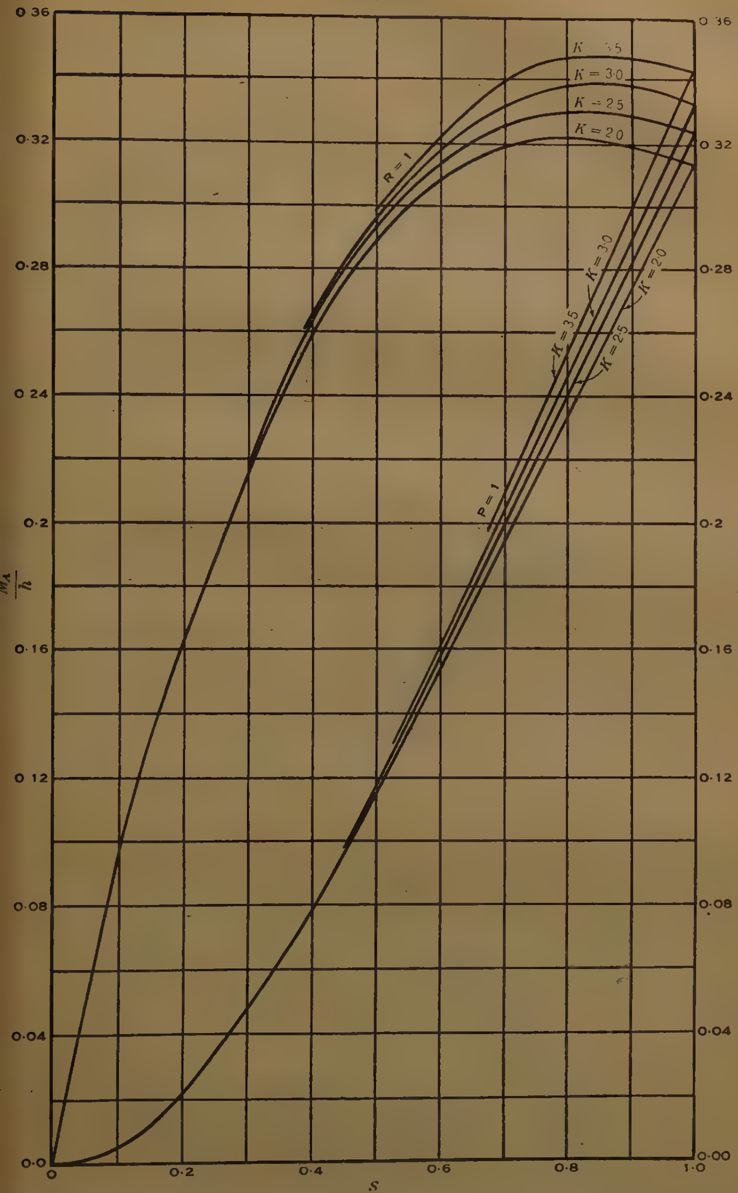
It is of considerable importance in design to ascertain whether the
nominally fixed ends, set into the ground on, say, a sleeper foundation

Fig. 10.



really act as fixed ends or as hinged ends. With the comparatively wid
(5 feet square) box rib, it is probable that there is a good deal of fixed-enc
effect owing to the large bearing area; on the other hand, the deflexio
of any part of these ribs is shown, both by test and by calculation, to b
very small, even under full design loading, and it would take very littl
cant of the bases to give a free-end effect. A full investigation has bee
made of this uncertainty in the cases of both fixed ends and free ends a
every stage of the problem. This investigation led to the interestin

Fig. 11.



scovery that it is safe and reasonably economical to design the rib for e maximum bending moment and shear that might arise in the free-ded condition. This conclusion applies, of course, only to a rib of nstant section and then, whatever bending moments and shears arise

Fig. 12.

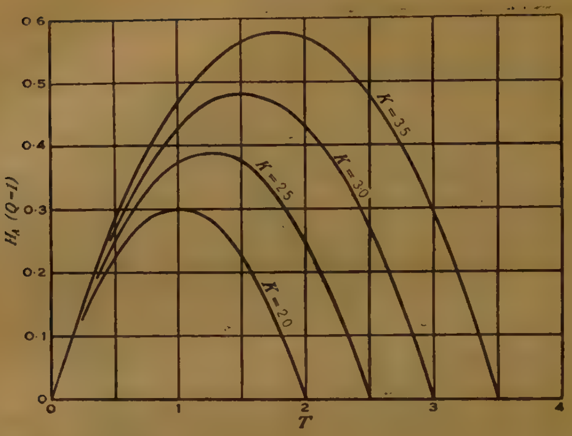


Fig. 13.

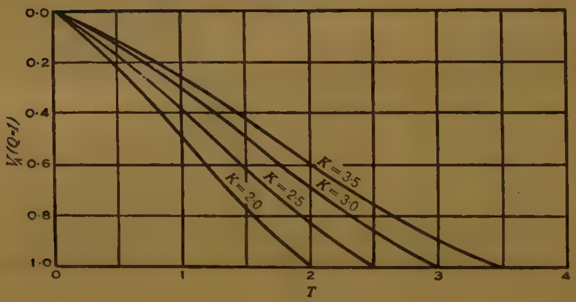
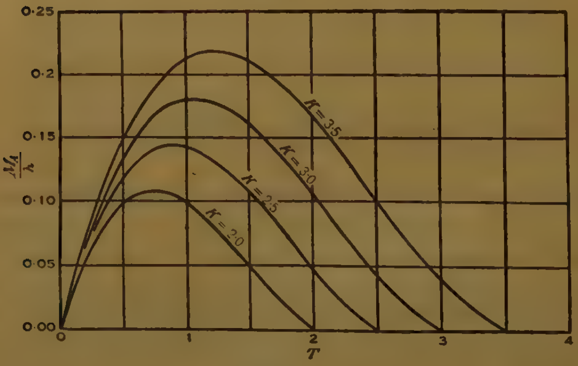


Fig. 14.



ue to fixed-ended effects, partial or full, the strength of the rib is more han adequate to meet them. The calculations, as will be noted from the quations on p. 315, are a good deal simpler on the free-ended basis.

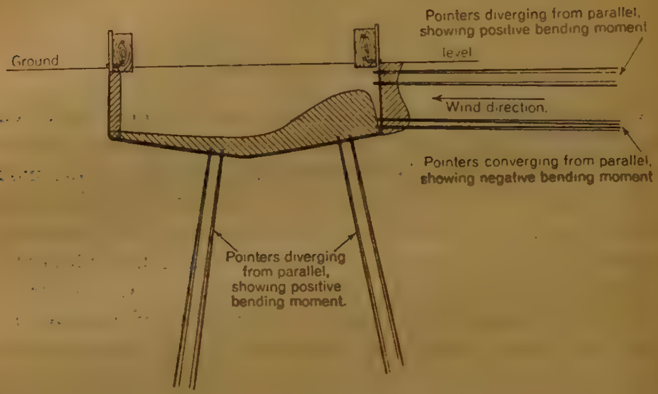
The Use of Models.

In the course of their investigations on bending moments and deflexions, nd in considering the general questions in hangar design, the Authors onstructed various models, which afforded great help. One model consisted of the complete framework of the hangar built up in iron wire of the ppropriate gauge to represent the actual strength of the members on the asis of their capacity as struts. This compromise was adopted because was not possible to get angles truly similar and small enough. By the heory of similar structures it may be shown that, if a model is true to cale and of the same material as the original, and if the applied loads are ll reduced in proportion to the square of the scale reduction, then relative eflexions in the model and the original will be directly proportional to heir sizes, and the unit stress (in lb. per square inch) in corresponding embers will actually be the same. Failure, which would normally be by rippling in such a model, could also be expected to occur at corresponding ress intensities and deflexions if the loading in either case were to be icreased enough. The wire model, being constructed with soldered rossing points, was certainly not an exact copy of a hangar rib, but it is, evertheless, interesting that it withstood, as it should under the theory f similarity, central loading proportionally intense to that applied to a est hangar rib without failure, and that the relative deflexions corresponded irly closely.

Another interesting model consisted of a flat strip of metal, bent to angar-rib shape, and provided with ends which may be made "fixed" or hinged" by the tightening or slackening of clamping screws. The outline f this model is shown in *Figs. 15* and *16* (p. 320). Applied loads could be ung on this strip by weights suspended on string (the weights being shown s small bags of shot). To apply such forces to the roof the rib was mounted pside down, whilst horizontal loads were applied by passing the strings ver small pulleys. The deflexion of such a flat-strip model is considerable id may be readily observed and plotted. For the simple observation of ending moment the Authors have applied to this strip model a visual rangement which, as far as they are aware, is a novelty for this purpose. wo or more long light needled-ended pointers are attached by screwing to tapped holes in the centre line of the strip, the holes being about $\frac{1}{2}$ inch part and the needles standing out parallel to each other when the strip unloaded, so that their ends are also about $\frac{1}{2}$ inch apart. When the rip is loaded with any system of forces a bending moment is indicated at e region where the pointers are attached. This bending moment is

positive or negative according as the tips of the pointers approach toward or separate from, each other.

Fig. 15.

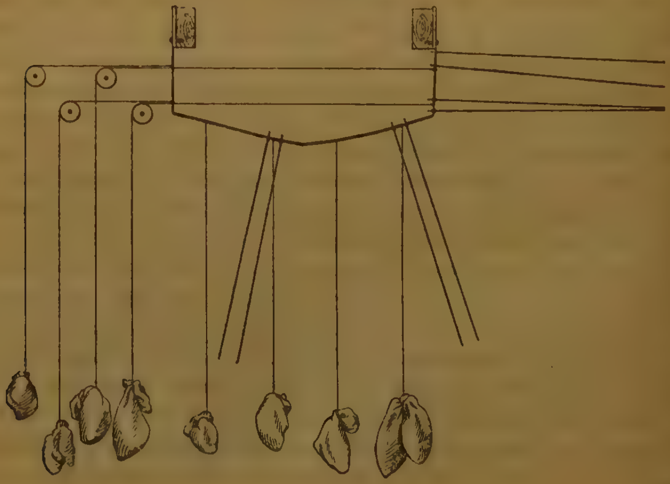


If the pointers are 10 inches long, R denotes the radius of curvatur and the "approach" of the tips is X inches (X is, of course, negative the tips move apart), then:

$$R = 10 \times \frac{\frac{1}{2}}{X} = \frac{5}{X} \text{ inches,}$$

and from the equation $M = \frac{EI}{R}$ the actual bending moment may be foun if required.

Fig. 16.



This model was not used with any pretentions to instrumental accuracy lthough it could probably be used to obtain numerical results), but even hen quite roughly set up it would be found to give a useful check on the lculated positions of the maxima and minima of the bending moments the fixed- and free-ended cases respectively. It also gives a quick visual emonstration of what may be quite a lengthy mathematical analysis, nd it is a safeguard against major errors such as the use of incorrect signs or instance, + instead of —) for reactions or moments.

The Authors suggest that the same principle could be usefully applied to cture-room demonstrations of elastic-arch problems and to the elucidation f complex building frames of variable cross-section.

"Normal" and "Emergency" Wind Conditions.

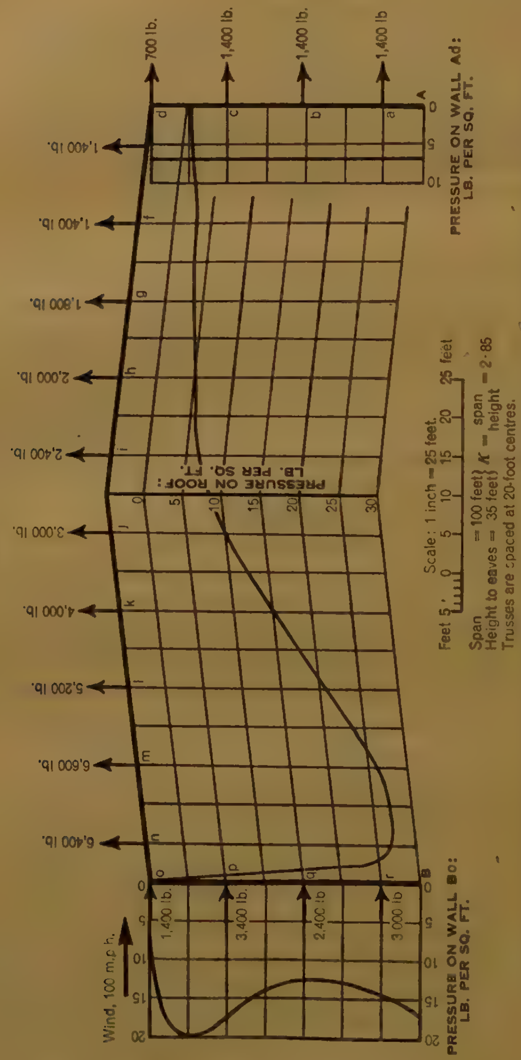
In *Fig. 17* (p. 322) which shows the curve of wind-pressure distribution plotted from the National Physical Laboratory's Report, the hangar is sumed to be in a closed condition (that is to say, all doors and windows e assumed to be shut), and that the covering of the hangar is strong and tact when the maximum wind blows. The frame of the hangar may then designed to resist these forces acting in conjunction with the dead load the steel framework and its covering (which is, of course, always present); is is the "normal" wind-load design.

It is now necessary to investigate what happens if the covering is not rong enough to resist the peak pressures upon it, and the sheeting is ther (*a*) blown in on the upper part of the windward wall or (*b*) sucked torn off on that part of the windward slope of the roof where the suction tensity is greatest. If, further, the external air in case (*a*), or the internal r in case (*b*) surges through the opening until there is statical equilibrium d the manometric pressure of the breached spot acts upon the whole terior of the shed, then what is the state of stability of the hangar? e the loads upon the ribs relieved or are they intensified? Is the shed t less likely to blow down if it has such a hole torn through it? (It ould at first appear that a large hole should relieve pressure differences on e sheeting.) These are considered to be the "emergency" wind con- tions and an investigation has been made of both the limiting cases re- red to. It will be seen later from the plotted loads and bending moments igs. 21 to 23 and *Figs. 25* to *27*, pp. 326 *et seq.*) that these emergency cases ght give rise to serious conditions should they ever occur with full effect. is, of course, open to question whether the full calculated extremes could er occur, for there would probably be a considerable relief of pressure cause of the general lack of air-tightness of the hangar and the short ration of such "immense" wind velocities, coupled with the inertia of steelwork and of the sheeting itself. Limiting conditions, however, always interesting to study and to allow for, if possible, in the design.

Examination of the pressure diagrams, *Figs. 20* (p. 325) and *24* (p. 329),

for either of the extreme cases, clearly shows that they are derived fro[m] the pressure diagram for the normal state of affairs (*Fig. 17*) simply b[y] changing the datum pressure. The datum is changed in case (*a*) by th[e]

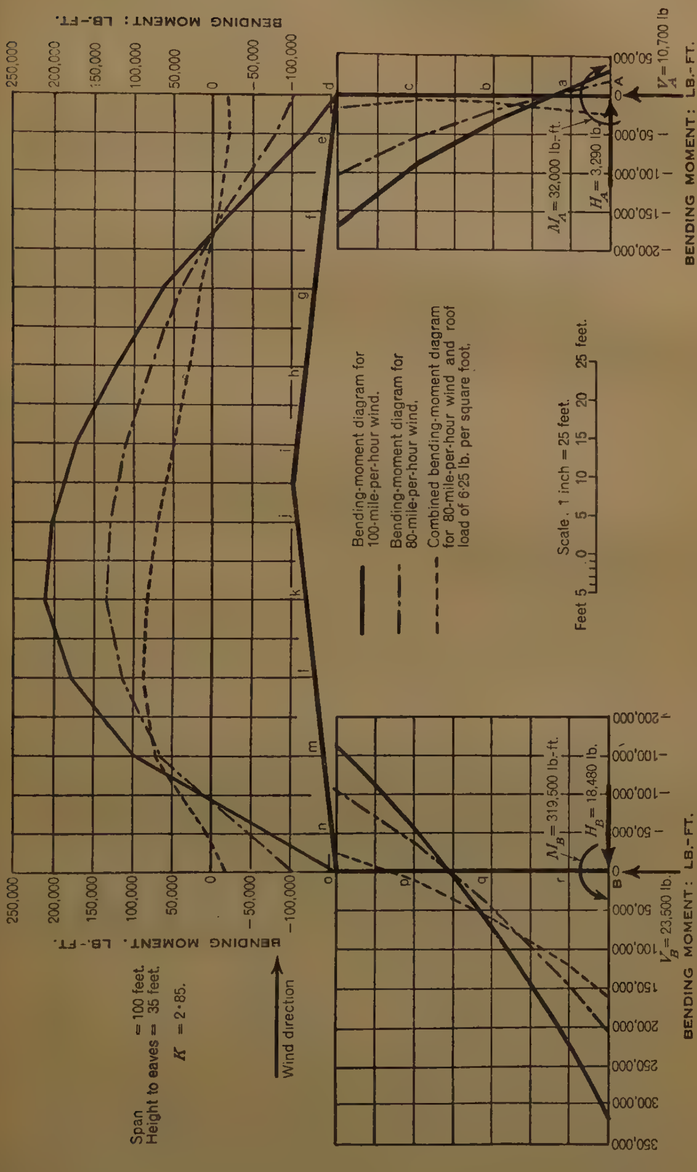
Fig. 17.



WIND-PRESSURE CURVES FOR "NORMAL" AIRTIGHT CONDITIONS AND THE RESULTANT PANEL LOADING ON THE RIB.

addition of the maximum pressure ordinate, and in case (*b*) by the deduc[-] tion of the maximum suction ordinate. The interior of the shed is the[n] at the actual wind-pressure just outside the hole, on the hypothesis of th[e] rest of the shed being air-tight.

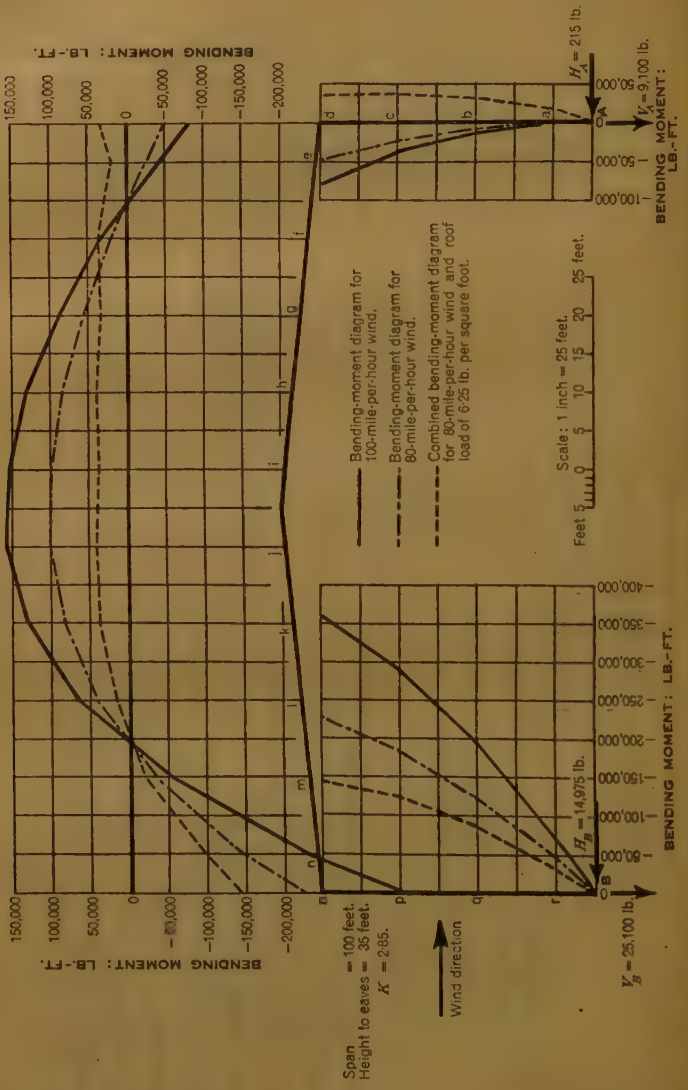
Fig. 18.



BENDING-MOMENT DIAGRAMS FOR "NORMAL" WIND LOADING: FIXED ENDS.

The derived bending moments, shown in *Figs. 22, 23, 26,* and *27,* d
not represent the only effects on the hangar ribs, for the dead-load momen
must also be taken into account. Thus, if the emergency wind conditio

Fig. 19.

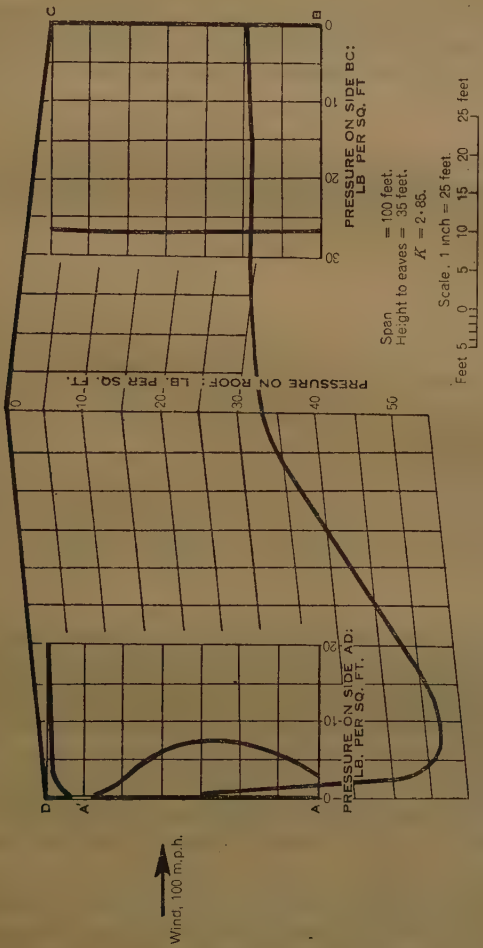


BENDING-MOMENT DIAGRAMS FOR "NORMAL" WIND CONDITIONS: HINGED ENDS.

are to be fully allowed for in this hangar, the ribs require to be twice
strong as if these emergency conditions be neglected or dealt with by oth
means. It should be noted that emergency conditions of comparab
magnitude may not necessarily be due to the ripping away of sheetin

ey may also arise, for example, if the doors on the windward side happen be open and those on the leeward side closed (in this case the wind is ssumed to be blowing parallel to the length of the hangar), or if there are entilator openings giving the same effects. A list of the conditions for omplete safety is as follows :—

Fig. 20.



PRESSURE CURVES SHOWING THE EFFECT OF A HOLE AT A′ ON THE CURVES SHOWN IN *Fig. 17.*

(1) The sheeting, its fixings, and the purlins, should be at least strong ough to withstand the maximum pressure or suction due to the highest ssible wind which has to be considered. Uplift or suction are even more portant than inward thrust where the design of the covering is concerned.

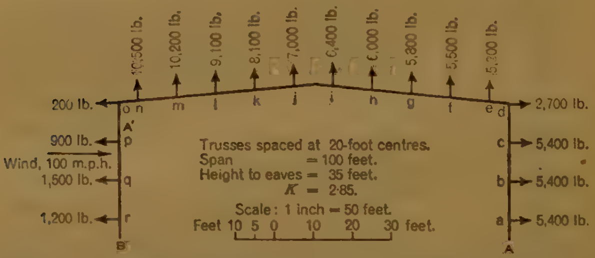
(2) Doors and windows (whether of glass panes or of flexible transparent terial) should be designed to withstand these limiting pressures.

(3) All doors and other openings should be tightly closed during hig winds.

(4) If the hangar is not heavy enough in itself to counteract the uplif due to the normal maximum wind-suction (and hangars of the type unde discussion are, generally, by no means heavy enough to resist the uplii of an 80- to 100-miles-per-hour wind), then the rib footings must b adequately buried or weighted down. The older building-rules, c course, give no indication whatever of the very dangerous uplift force which may arise in light hangars of low roof-slope. *Figs. 17* and *2* clearly indicate the unexpected and abnormal magnitude of the uplif forces.

Fulfilment of all these conditions would, it is considered, restrict th hangar to the action of the "normal" wind forces and the design woul

Fig. 21.



PANEL LOADING ON THE RIB RESULTING FROM THE WIND-PRESSURES SHOWN IN *Fig. 20.*

be fully determinate and basically sound. It is reasonable to assume tha the doors, normally, would be shut as the wind rose. One simple way o allowing for the emergency conditions (if not fully allowed for in the design of the rib) should be mentioned. In some of the actual hangars so far con structed there are strips, 5 feet deep, of light-transmitting material fixed beneath the eaves throughout the perimeter of the sheds. This materia was formally oiled canvas. But more recently "Windolite" has been used. Either material is, of course, necessarily weaker than the rest o the covering, and if a section of it is blown in or out by ultra-high wind pressures, say, for example, on the windward wall, then as soon as the pres sure rises inside the shed the same material is almost certain to be blown out on the leeward side also, thereby eliminating the pressure as soon as i arises. Thus it is believed that if ever such wind forces arose on a hanga of this kind, this band of weaker covering material passing right round the shed would probably act as a kind of safety-valve, which would blow away and so relieve all excess pressures on the rest of the sheeting, and on the ribs before any further damage was caused. In actual practice it was found that the original oiled canvas deteriorated and blew out after a time in

rdinary gales; "Windolite" is much stronger if well secured in the first lace, and up to the present it has not been affected even by the strongest vinds that have blown in the past year.

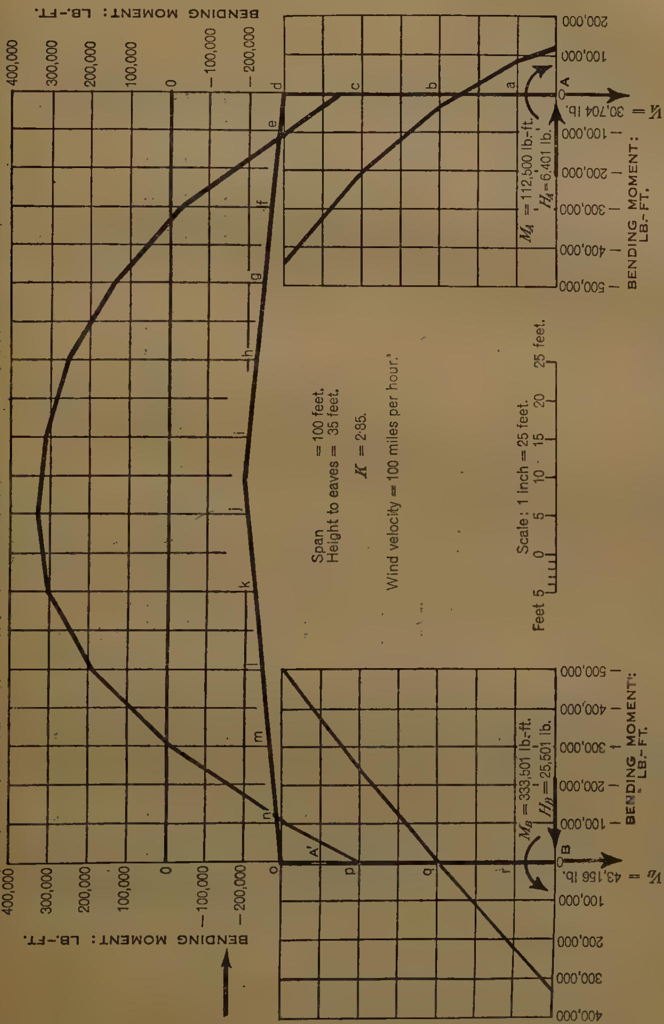


Fig. 22. Bending-Moment Diagrams for "Emergency" Conditions: Hole at A′. Fixed Ends.

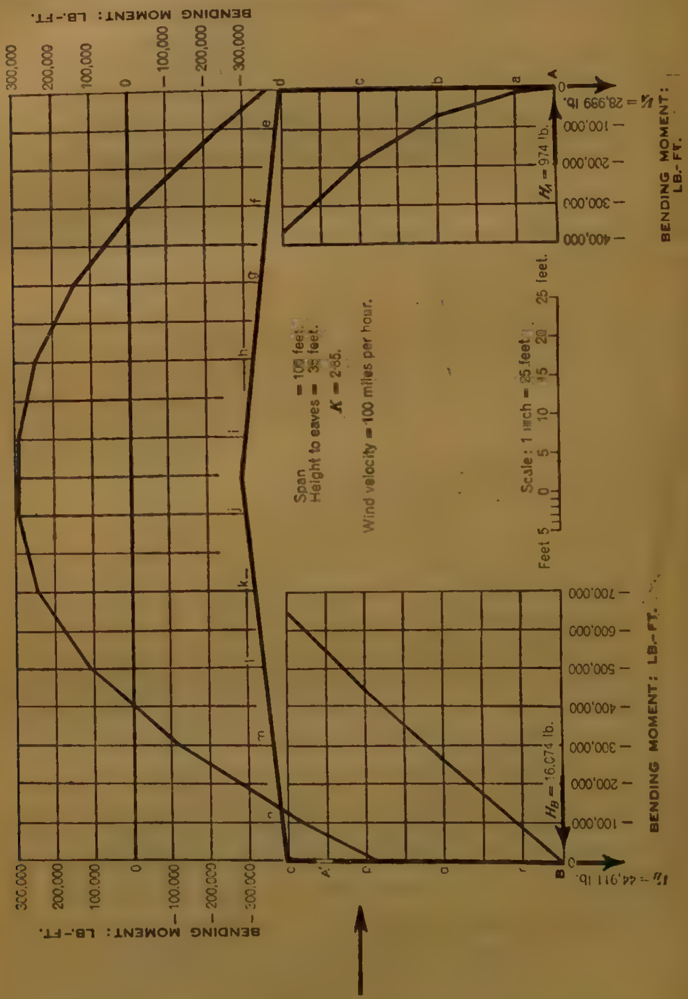
Dead-Load Capacity of the Rib.

If designed for the normal effects of an 80-mile-per-hour wind it is ound that the capacity of the rib to carry vertical loading in the form of eight of structure and sheeting, a small snow allowance, or a load-

carrying runway attached to the underside of the rib within the shed, i
sufficient for most ordinary needs.

In the applied dead-load and dead-load bending-moment diagrams
Figs. 28 to *30* (pp. 333 *et seq.*), the vertical loading has, for simplicity, been

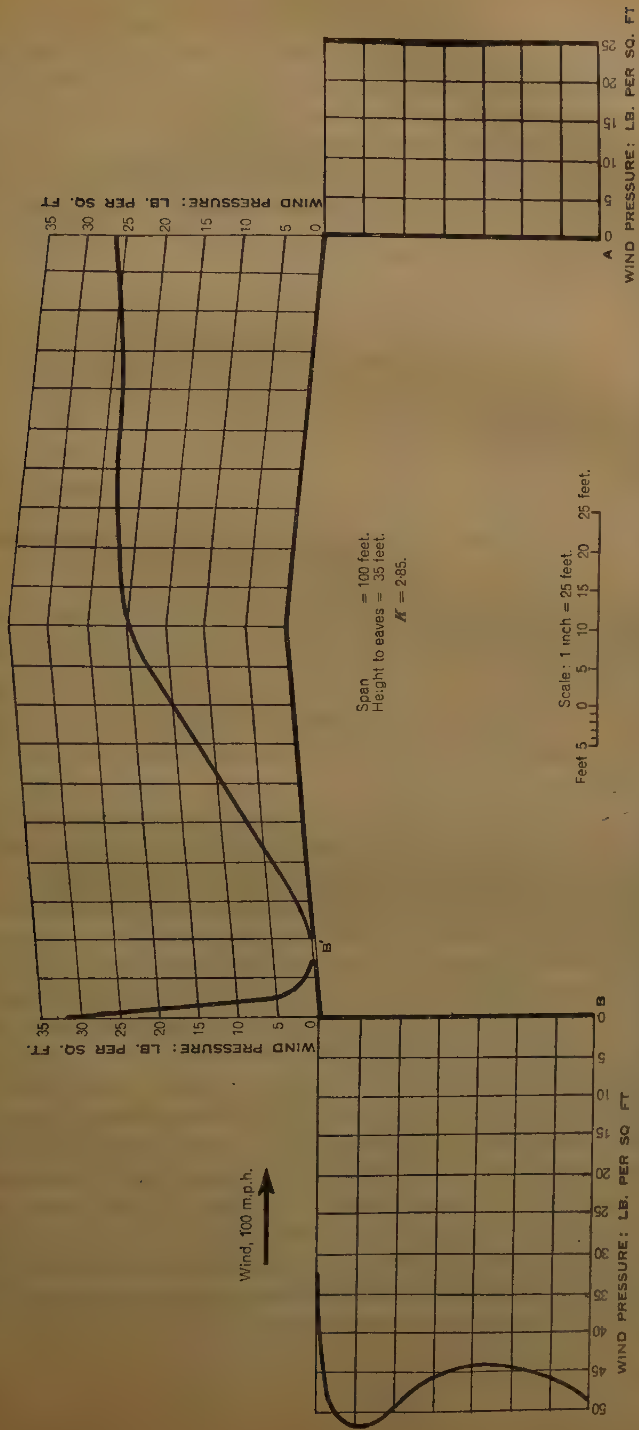
Fig. 23.



BENDING-MOMENT DIAGRAMS FOR "EMERGENCY" CONDITIONS: HOLE AT 'A'.
HINGED ENDS.

taken at 10 lb. per square foot. In the hangar rib under review the tot
dead load which would give the same bending moment as the maximu
which would be caused by an 80-mile-per-hour wind, will be found to
approximately 15 lb. per square foot over the whole roof. The permane
dead-load is 3 lb. per square foot, due to the rib and the purlins, and abo
$1\frac{1}{4}$ or $3\frac{3}{4}$ lb. per square foot for corrugated-iron or reinforced-asbesto

Fig. 24.

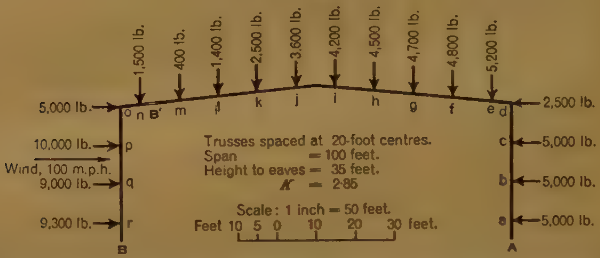


PRESSURE CURVES SHOWING THE EFFECT OF A HOLE AT B′ ON THE CURVES SHOWN IN *Fig. 17.*

cement sheeting respectively. Thus there is an allowable reserve for sno load of about 8 to 10 lb. per square foot. Alternatively, a load of abou 2 tons can easily be supported at any panel-point of the rib within th shed; this may be most useful when repairing and overhauling aircraf or when fitting runways for moving heavy gear.

It is to be noted from the bending-moment diagrams that the norm wind loads and the dead loads do not act together to increase stresse

Fig. 25.



Panel Loading on the Rib Resulting from the Wind-Pressures Shown in *Fig. 24.*

Strange as it may seem, the wind actually relieves, by its suction effect the roof, the dead-load stresses in the rib in all cases except when there i hole in the roof.

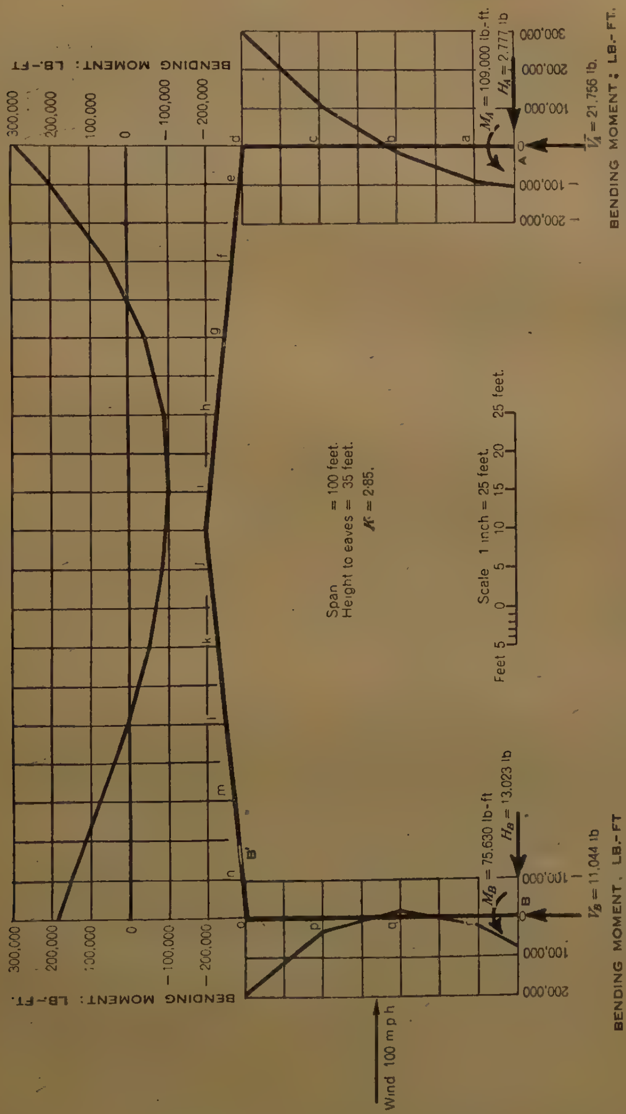
Door and Frontage Forces.

It has already been mentioned, and it is clear from *Figs.* 2, th if the wind is blowing parallel to the length of the hangar, the w forces on the end of the hangar are of the same order of magnitude as forces due to a wind blowing perpendicular to the length of the hang In designing the doors of the hangar under consideration an aver pressure of 17 lb. per square foot was assumed. The design of the doors like the box construction of the ribs, of a proprietary form, and while doors give full end-opening of the shed they have only a short exter overhang (this is achieved by the arrangement of double surfaces t scoping within the main sliding leaves). The doors are suspended fr Coburn tracks which themselves are supported by the end ribs. horizontal member to which the track is attached hangs from the and acts both as an extra tension member for it and also as one chord horizontal wind-truss. The other chord of this horizontal truss ha below the second rib, whilst between the chords lies the horizontal w bracing, the whole acting as a girder which transfers the upper part of end wind-pressure to the walls of the hangar, where it is carried to grou level by special bracing between the stanchions of the two end ribs. addition the two end ribs are braced throughout across the roof (Figs. Plate 1).

Shear Loads and Corner Loads in the Rib.

The complete design of the rib is relatively easy once the wind- and dead-load end-reactions and bending-moment diagrams have been deter-

Fig. 26.

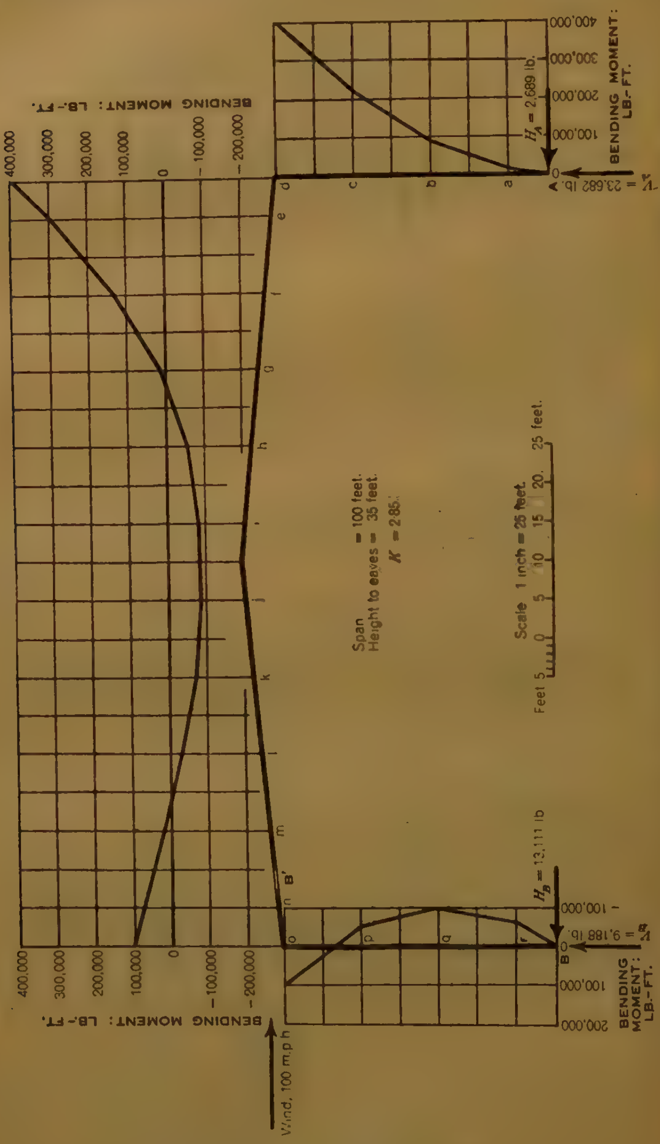


Bending-Moment Diagrams for "Emergency" Conditions: Hole at B', Fixed Ends.

mined. The maximum reaction, whether horizontal or vertical, in either the fixed- or free-ended cases, represents the shear for which the rib should be designed (the load being shared equally between tension and compression

bars, and the strut length of the latter being taken at half their total length, as already mentioned). The maximum bending moment gives the required load in the chords.

Fig. 27.



Bending-Moment Diagrams for "Emergency" Conditions: Hole at B'. Hinged Ends.

In calculating the load in the main corner tie and its connexions the figure of $\sqrt{2}$ times the chord load may be used.

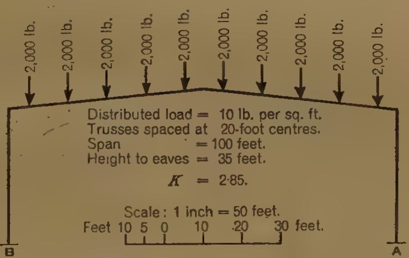
Conclusions.

(1) In exposed aero-hangars or sheds with flat roof-slope (about 5 legrees), the wind-pressure on the windward side of the building is normally f less intensity, and has less effect on the correct design of the building, than he wind-suction which occurs on the roof. These negative pressures on he roof have their highest values on the windward slope near the eaves, nd diminish towards the leeward eaves, with no sudden change at the idge. There is normally no positive pressure on the roof no matter in vhat direction the wind blows.

(2) In designing such a large aero-hangar or building, of whatever hape, it is advisable to obtain a wind-tunnel-test report giving the pressure listribution. Observations on actual buildings have been found to confirm he tunnel tests with considerable accuracy.

(3) The tunnel tests indicate not only the wind forces on a closed-in tructure, but they also show the necessity for the adequate strengthening

Fig. 28.



Dead-Load Distribution (Including Light Snow-Load).

f the covering of the shed, including windows and doors, and they give he values of the air-pressures or suctions which these should be able to esist in a wind of any specified velocity. The tests indicate also the "emergency" pressures that may arise on the building structure should here be any opening in the covering, caused by accident or otherwise.

(4) The capacity of a large exposed building to withstand any accilental holing in a high wind, or the leaving open of doors or windows, hould be carefully considered when designing the building.

(5) When a high wind blows through an open doorway or window into ny closed building there is always a considerable uplift effect on the oof. It is considered, therefore, that even in normal roof trusses of rdinary span and pitch, it is very desirable to make the truss members apable of withstanding reversal of stress. Furthermore, the roof covering hould always be adequately secured against uplift forces.

(6) If the hangar itself is not heavy enough to withstand the uplift effects it should be adequately anchored down to prevent its bases being iprooted in severe wind.

(7) Winds from any direction lessen the dead-load stresses excep when there is a hole in the roof.

(8) The most stable form of light building construction is considered t

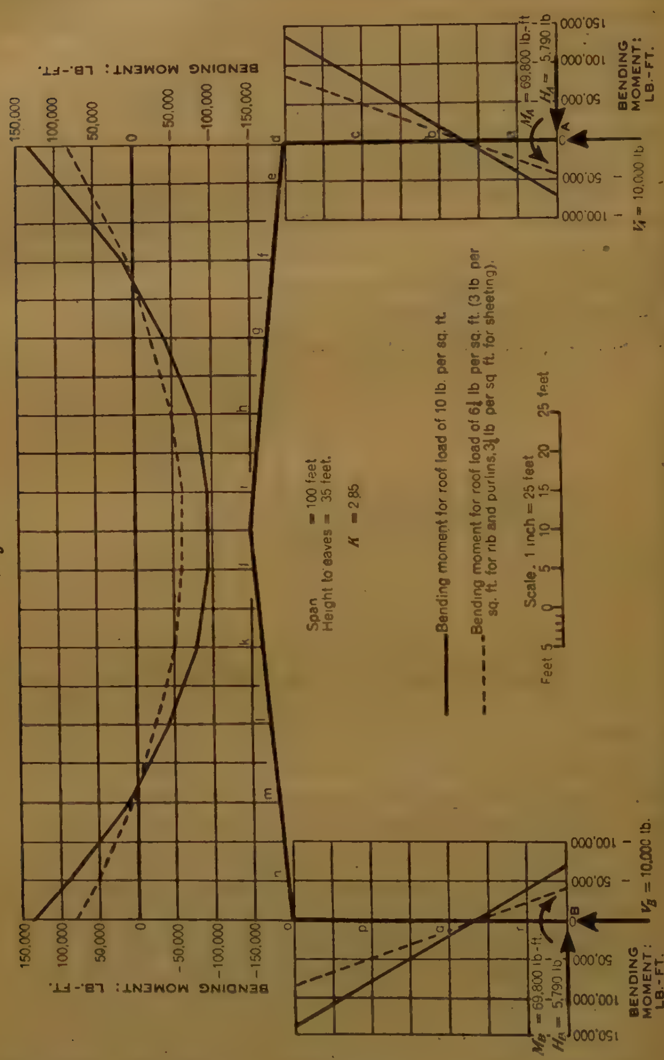


Fig. 29.

BENDING-MOMENT DIAGRAMS FOR DEAD LOADS: FIXED ENDS.

be the lattice rib of as wide a box-section as convenient; the cross-secti should be constant right to the foundation bases.

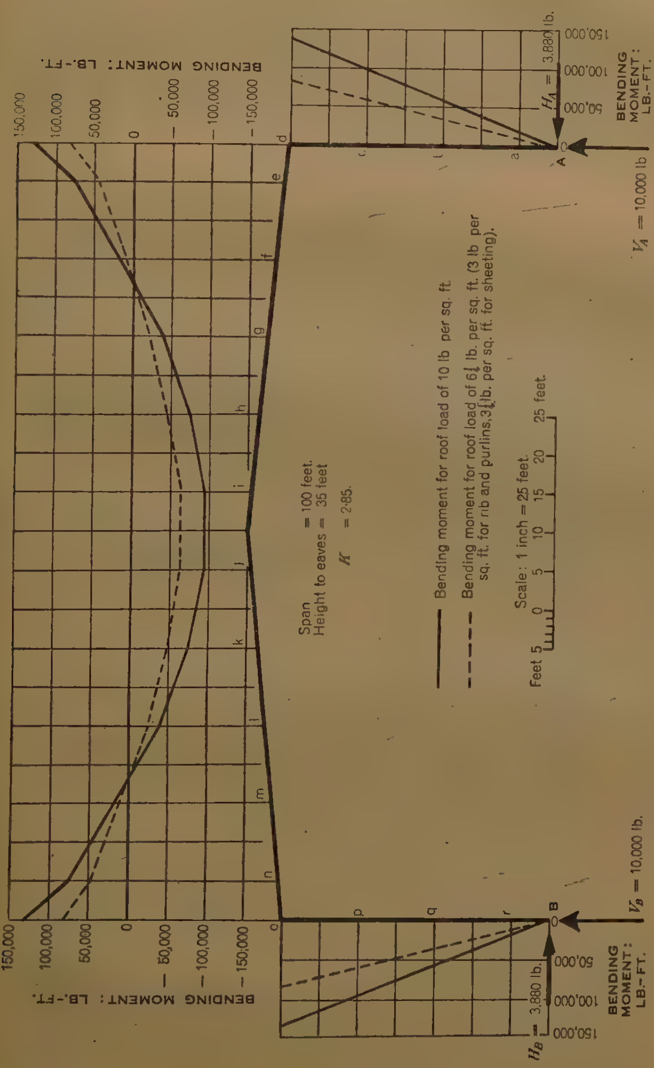
(9) The maximum bending moment in the rib for "hinged ends" of the same order as that for "fixed ends."

(10) The roof ribs, as designed for an 80-mile-per-hour wind with

actor of safety of $1\frac{1}{2}$, are found after 3 years' experience to be adequate or small snow loads.

(11) For countries where the winter is severe and the snow load may

Fig. 30.



BENDING-MOMENT DIAGRAMS FOR DEAD LOADS: HINGED ENDS.

ry from 15 to 36 lb. per square foot the ribs need be designed against s vertical loading only, and, if continuous and capable of taking full versals of stress, they will then be adequate for any wind.

(12) The box-lattice rib has advantages, not only for service conditions

which require stability under bombing and ease of repair if damaged, b also in its capacity as a girder to take reversals of stress due to wind upli Single-girder ribs or simple roof trusses are not usually so well able to ca compression in the lower tie or chord, and are not considered to be adaptable to meet all the uses that a hangar of the type under conside tion might be called upon to serve. Moreover, the bolted lattice system construction lends itself to rapid manufacture and " hot-dip " galvanizi

(13) The Authors suggest that there is still much room for investigati on roofs of different slopes and shapes.

Acknowledgements.

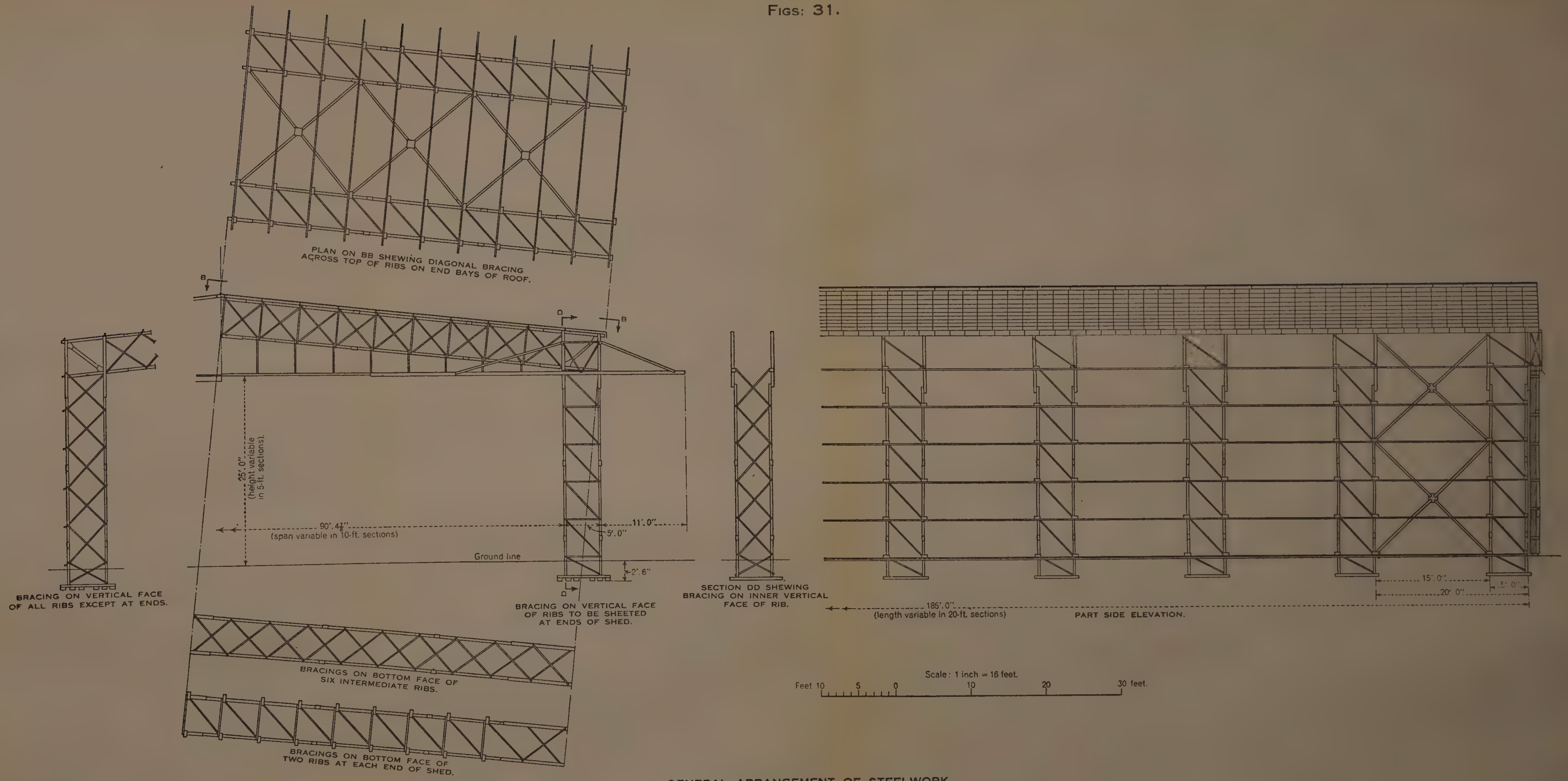
The Authors are indebted to Mr. A. Fage, and to Mr. A. Baile M.Sc., Assoc. M. Inst. C.E., of the National Physical Laboratory, their valued suggestions and advice, and to Mr. C. O. Boyse, B.S Assoc. M. Inst. C.E., and Mr. D. G. White-Parsons, Assoc. M. Inst. C. of Callender's Cable & Construction Company, Ltd., for their very imp tant contributions to the matter in this Paper. Dr. R. Pendennis Wall M.Sc., M. Inst. C.E., also gave valuable suggestions for the photographi of fluid flow by the Ahlborn method.

Confirmatory tests on the full-size rib were conducted by Mess Painter Brothers, Ltd., of Hereford, with their very complete and accura electrically-operated dynamometer tower-testing equipment ; the hang also are fabricated by this firm.

The Paper is accompanied by twenty-seven sheets of drawings a thirteen photographs, from some of which the Figures in the text and t half-tone page-plate have been prepared.

SOME ASPECTS OF AERO-HANGAR DESIGN.

Figs: 31.



GENERAL ARRANGEMENT OF STEELWORK.

Paper No. 5202.

"The Deterioration of Concrete in Contact with Sewage."[1]

By Solomon Simon Morris, B.Sc., Assoc. M. Inst. C.E.

(*Ordered by the Council to be published with written discussion*[2].)

TABLE OF CONTENTS.

Introduction.

LTHOUGH the decomposition of concrete under certain conditions has been nown, and in some cases understood, for many years, the particular type deterioration usually associated with sewage-carrying drains still mains largely unexplained by sewerage engineers.

Whenever concrete comes into contact with sewage, decomposition the former is not necessarily inevitable. Normal sewage, at ordinary mperature and in the absence of air currents, does not produce any sintegration of cement mortar, or concrete. In cesspools, where the wage is exceedingly strong, the cement lining to brick tanks shows no cay; and there are innumerable instances of concrete reservoirs and wer pipes which have been in use for many years without disintegration coming apparent[3].

In Capetown, however, the effect of sewage on concrete carriers and tainers has been extraordinarily noticeable, and investigations were cently undertaken in order to determine, as accurately as possible, the uses responsible for the trouble.

Capetown is not the only place where this undesirable and objectionable ture has been prominent in sewage collectors. In a Paper by Mr.

[1] This Paper is an extract from a communication entitled "The Main Drainage Plumstead to Muizenberg, Cape Town", the MS. and illustrations of which may be n in the Institution library.—Sec. Inst. C.E.

[2] Correspondence on this Paper can be accepted until the 15th June, 1940, and l be published in the Institution Journal for October 1940.—Sec. Inst. C.E.

[3] C. F. Marsh and William Dunn, "Manual of Reinforced Concrete." London nstable and Co.), 1922.

A. O. W. D. Pinson [1] a description is given of the early working of t
drainage system of Cairo [2] and the difficulties which have arisen in connexi
with the ventilation of the collector and the corrosion of the concre
therein.

Not only are the main sewage collectors being attacked in Capetow
but the destruction of concrete has also been observed in the sumps of t
main and subsidiary pumping stations, and also in certain concrete flum
at the Southern Suburbs disposal works situated at Athlone.

The deterioration of concrete referred to above is usually attributed
sulphur bacteria. This is only partly true, since the action involves
much more complicated process wherein the sulphur bacteria play o
an auxilliary, albeit a most important, role.

Physical Characteristics.

The physical characteristic usually displayed is yellowish-white fla
coating on the concrete, which is gradually broken down. This involve
considerable loss of strength, the concrete being greatly reduced in thickn
by intermittent crumbling and, very often, becoming as soft as putty.

Those parts which are entirely immersed in sewage rarely display sig
of sulphur bacteria. On the other hand, complete exposure to the air
equally as good in preventing the action as total exclusion therefrom.

Deterioration Effects at Cape Town.

Physical investigations carried out under the direction of Mr. W.
Hoskins, Assoc. M. Inst. C.E., Roads and Drainage Engineer, into t
nature and conditions under which the sulphur-bacterial attacks occur
in Capetown, have revealed much useful and valuable information, and t
results of these investigations are summarized as follows :—

(1) *Main Pumping Station.*

The sides of the pumping wells and cross struts, well above any possi
contact with sewage, show marked signs of deterioration.

The effect is much greater in that portion of the well in which the pum
are operating to the disposal works than in the portion of the well on t
stormwater side. The deleterious effect appears here to be purely gaseo
and the reason for it being greater on the sewage side is probably due
one or more of the following causes :

(*a*) the sewage being churned up daily by the revolving scree

[1] "Cairo Main Drainage Extensions." Minutes of Proceedings, Inst. C.E., vol.
(1930–31, Part I), p. 112.

[2] C. C. James, "The Main Drainage of Cairo." Minutes of Proceedings Inst. C
vol. ccii (1915–16, Part II), p. 57.

whilst the stormwater side is quiescent for the greater part of the year and is protected by the floating scum;

(b) the ventilating-fan suction-pipe being on the stormwater side.

2) *Liesbeek, Kromboom, and Zwart River Intercepting Sewers.*

The Liesbeek, Kromboom, and Zwart River intercepting sewers do ot show any signs of deterioration, this freedom from attack being probably ue to one or more of the following causes:

(a) the sewage being almost entirely domestic;

(b) a high velocity of flow;

(c) the non-existence of sub-pumping stations in which retention occurs;

(d) the absence of splashing where the mains enter the intercepting sewers.

3) *Mowbray–Woodstock and Maitland Sewers.*

The Mowbray–Woodstock and Maitland sewers are affected badly in arts. Deterioration is worst at the positions where the rising mains from ie sub-stations enter the gravitational sewers, also where the discharge om the abattoirs enter the Maitland intercepting sewer.

This may be attributed to:

(a) the areas being industrial, the sewage, therefore, not being entirely of a domestic character;

(b) retention in the sub-pumping stations, permitting the sewage to become septic;

(c) agitation and creation of gases where sewage from the rising mains first enters the gravitational sewer.

(This effect appears to be gradually overcome by dilution and steady flow as the discharge from the sub-station intermixes with the greater volume carried by the intercepting sewer);

and (d) the fact that sewage from the abattoirs is of a very strong and peculiar character, and is also liable to be rendered septic by retention in the pumping-well.

The condition of these sewers is probably aggravated by the checking ventilation owing to the siphon under the Black River canal.

Glazed-Ware Pipes and Manhole Steps.

At the intersection of the abattoirs sewer with the Maitland intercepting ver, a 12-inch-diameter glazed stoneware pipe makes connexion with e ovoid concrete sewer. The concrete work is noticeably affected, but e glazed stoneware pipe is in perfect condition. In some of the man- les the step-irons were found to be in an advanced state of decay.

(5) *Sub-Pumping Stations.*

There are no indications of corrosion found in the pumping wells of tl sub-stations; it is, however, difficult to examine these wells thoroughly.

The manholes, immediately before entry to the sub-stations, have bee found to be unaffected.

Corrosion is very marked in the pumping well at the Vyge-Kraal statio which deals with sewage after treatment in the sedimentation tanks.

A point worthy of notice is that decay is most advanced near the ent of an influent pipe where disturbance occurs, whereas the far end of tl sump shows no indications.

(6) *Disposal Works.*

The influent channels to the sedimentation tanks show marked signs attack, as do also the effluent channels, although to a lesser degree. Tl gas-vents and tops of the tank sides are also affected.

The concrete carrier, where covered by boards, is seriously affected.

This may be attributed to the covering of the tanks and carrier stoppi ventilation.

Chemical Analysis.

Scientific investigations have now established the fact that the corrosi of concrete takes place in two separate stages as a result of at least tv different bacteriological processes. These are:

(1) the formation of hydrogen sulphide;

and (2) the oxidation of hydrogen sulphide to sulphuric acid.

Stage 1.

The formation of hydrogen sulphide is brought about by either:

(*a*) the reduction of mineral sulphates by such organisms *Spirrilum desulphuricans*,

or (*b*) splitting up of the only three sulphur-containing animo aci (cystine, cysteine, and glutathione), by a variety of saprophyt micro-organisms.

The bacterial reduction of sulphates, which is the most significant of tl two actions, appears to be an oxidation of organic matter with the aid the inorganic combined sulphate-oxygen as typified in the followi equation, in which *c* represents the organic compound and *m* a metal inorganic base.

$$\begin{array}{ccccccccccc} 2c & + & mSO_4 & + & H_2O & = & mCO_3 & + & CO_2 & + & H_2S \\ \text{(organic} & & \text{(mineral} & & \text{(water)} & & \text{(mineral} & & \text{(carbon} & & \text{(hydrog} \\ \text{compound)} & & \text{sulphate)} & & & & \text{carbonate)} & & \text{dioxide)} & & \text{sulphid} \end{array}$$

The bacterium in question has been named *Spirrilum desulphuricans* nd is a non-sporing and anaerobic organism. Other similar organisms have een isolated, but these differ in the nature of the environment required for ptimum effect.

The formation of hydrogen sulphide, as explained in (*b*), is usually roduced by the numerous forms of bacteria commonly existent in sewage t nearly every stage of becoming septic.

Stage 2.

The second step is the absorption of this hydrogen sulphide by the true ulphur bacteria. True sulphur bacteria are defined as those which, during heir metabolism, absorb hydrogen sulphide, oxidize it to sulphur, and store he sulphur within the bacterial cell in the form of granules. This sulphur s then excreted and oxidized either to sulphuric acid or to sulphates ccording to the following two equations :

$$\text{(I)}\quad \underset{\text{(hydrogen sulphide)}}{2H_2S} + \underset{\text{(oxygen)}}{O_2} = \underset{\text{(water)}}{H_2O} + \underset{\text{(sulphur)}}{S}$$

$$\text{(II)}\quad \underset{\text{(sulphur)}}{S_2} + \underset{\text{(oxygen)}}{3O_2} + \underset{\text{(water)}}{2H_2O} = \underset{\text{(sulphuric acid)}}{2H_2SO_4}$$

It is this sulphuric acid which is directly responsible for the decomposition of the concrete.

It must be remembered that these changes do not take place under all onditions. For each change there are definite environments essential for ptimum development of the particular bacteria responsible for the change. Thus if the *p*H-value, oxygen pressure, temperature, amount of organic naterial, or any other condition is not suitable to optimum development f some bacterium taking part in the formation of sulphuric acid, then he subsequent corrosion will be retarded.

Prevention of Deterioration.

To prevent the corrosion of concrete, therefore, it is desirable to avoid he formation of septic sewage with corresponding bacterial flora, involving he production of hydrogen sulphide.

When the latter is already present, its oxidation to sulphuric acid hould be prevented by taking precautions to minimize the conditions avourable to the development of true sulphur bacteria.

As these are unable to exist in large concentrations of oxygen, or nder well-oxidized conditions, the preventive measures indicated are : a) adequate ventilation, (*b*) a completely filled system, (*c*) chemical reatment, (*d*) the use of cast iron for mains, wherever possible.

Recently, in Capetown, attempts were made to discover which materials

would most successfully resist corrosion engendered by the action o sewage.

Experimental patches of different cement plasters were placed in th sewage-well at the main pumping station and their resisting qualitie carefully observed. As the cost of chiselling off the affected portions woul have been excessive for large areas, one set of patches was placed ove chiselled bases whilst the other set was placed on the old surface after th affected concrete had been well wire-brushed.

The results of these tests are given in Table I. They indicate quit clearly that " Ciment Fondu " was definitely the most resistant of the thre plasters used, and that it was not necessary to resort to chiselling th affected concrete away before applying the plaster, provided that thi concrete was well cleaned with a wire brush before being repaired.

Acknowledgements.

Much of the information enabling the compilation of this Paper ha been made available by permission of Mr. W. N. Hoskins, Assoc. M. Inst C.E., Roads and Drainage Engineer, and Mr. E. H. Croghan, M.A., Chie Chemist, and the Author is greatly indebted to them for their kindnes in allowing the use thereof.

The communication from which the Paper has been extracted i accompanied by one map.

PATCHES AT THE MAIN PUMPING STATION.

marks on inspection.			
	Old surface wire-brushed.		
ndu."	Cape Portland cement.	"Ferrocrete."	"Ciment Fondu."
uare	12 inches square	12 inches square	12 inches square
	No change	No change	No change
	"	"	"
all re-	Peels off when hit. Slightly affected at edges.	Corner chipped off. Otherwise sound.	Sound, but can be removed with chisel.
Bond	Affected for ½-inch depth. Bond weak. Not as powdery as other cape portland cement.	Affected for ½-inch depth. Not yet powdery. Bond fair.	Not affected. Bond fair.

Table I.

Students' Paper No. 962.

"An Investigation of Stresses in a Three-Hinged Stiffened Suspension-Bridge."

By JACK WILLIAM RODERICK, M.Sc., Stud. Inst. C.E.

(*Ordered by the Council to be published in abstract form*[1].)

ONSIDERABLE research has been done on the suspension-bridge, articularly in America, but in most cases investigators have confined their ttention to the structure with only two hinges. Authors of textbooks enerally treat the three-hinged bridge according to the approximate, or lastic, theory, and those who include the more exact methods rarely go urther than to indicate how the analysis may be carried out. Further-nore, no experimental work appears to have been done to check these heories when applied to this type of suspension-bridge, and to demonstrate nder what conditions economy results from the use of the more exact nalysis.

The object of this investigation was to determine to what extent certain esign-formulas may be justified, by tests on a structural model of a sus-ension-bridge. The tests were limited to two groups :—

(1) The measurement of the bending moments in the stiffening truss.

(2) The determination of the distribution of loading in the suspenders.

No account was taken of temperature-effects. Whilst it is realized hat there are several other quantities worthy of consideration, those hosen are thought to be the most significant in the evolution of design-ormulas.

The prototype is of the three-hinged type, having a span of 120 feet, nd a cable-sag of 12 feet. The backstays are straight and are inclined t the same angle as that which the main cable makes with the towers, he latter, for the purpose of model-design, being assumed rigid. The ridge is symmetrical in all respects, so that the investigation had only o be made for half the span.

The model consisted essentially of a single main cable passing over ulleys supported on heavy angle-brackets, which were assumed rigid, as

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[1] The MS. and illustrations may be seen in the Institution Library.—SEC. INST. .E.

were those supporting the ends of the stiffening truss. The truss, for convenience of construction, was made up of two parallel bars, of square section, connected at the panel-points by cross-pieces and suspended from the cable by wire suspenders. Thus the model corresponded in effect to one-half of the full-size structure cut along a vertical plane through the longitudinal centre-line. The loading bars suspended from the stiffening truss were necessary to produce the correct dead-load conditions. The dimensions of all components were obtained by applying the principle of similitude to the full-size structure. The derivation and operation of the necessary scale-factors are given fully in the Paper.

When once the overall characteristics of the design of the prototype had been ascertained, the order of procedure was as follows :—

(1) The application of the principles of similitude to the prototype to obtain the proportions of the model.
(2) The method of construction.
(3) The design and detailing of the model, together with the necessary supports.
(4) The manufacture of model-parts and the erection of the model.
(5) The design and manufacture of instruments and apparatus for testing purposes.
(6) The survey and adjustment of the model.
(7) The observation of the resultant strains and bending moments.
(8) The reduction, translation, and preparation of a summary of the observed data.
(9) The comparison of this data with theoretical values.

As regards the instruments, the measurements to be made were: (*a*) the bending moment at any point along the truss, and (*b*) the extension of the suspenders, and hence the loads in them. It was found that there were no standard instruments suitable for these purposes, for those considered proved to be either unadaptable or too heavy. Thus both instruments had to be designed and manufactured for the particular tasks.

It was considered that by far the most satisfactory method of measuring the bending moments occurring in the stiffening truss was that used by Messrs. G. E. Beggs, R. E. Davis, and H. E. Davis upon models of the San Francisco–Oakland Bay suspension-bridge [1]. This consisted of measuring the relative rotation of two sectional planes at a known distance apart. Two vertical arms, attached to the truss at the extremities of a known gauge-length, supported a light cross-bar at their ends. It was attached to the one arm and free to move relative to the other, the movement being a measure of the bending moment producing it.

The extensometer for measuring the loads in the suspenders was of the mirror type and was used in conjunction with telescopes and illuminated

[1] "Tests on Structural Models of the Proposed San Francisco–Oakland Suspension Bridge." University of California, Publications in Engineering, vol. 3, p. 59.

scales. Two short lever arms, their fulcrums being provided by an external stand, were attached to the suspender at a known distance apart. On the levers were set mirrors whose rotations were measured by the displacements of the images of the scales relative to the cross-hairs of the respective telescopes. The difference in those scale readings was a measure of the extension of the suspender, and hence of the load in it.

By means of those instruments the bending moments in the truss and the loads taken by the suspenders were measured for three types of loading, namely :

(1) concentrated loads ; (2) a load distributed over a length less than the span ; and (3) a load distributed over a length greater than the span.

Two theories have been fully presented in the Paper, one of which is approximate ; the other is generally described as more exact. The approximate, or elastic, theory achieves its simplicity by neglecting entirely the effect of deformation after loading ; namely, the deflexion of the truss, the departure of the cable-curve from its initial parabolic form, the extension of the cable, and the extension of the suspenders. Such a theory is reasonable for a bridge of short span or for one having a heavy inflexible truss, but for one of considerable length or possessing a comparatively flexible truss, the assumptions are not justified. It is the study of the effect of these deformations which constitutes the basis of this investigation.

The dimensions of the model were such as to give considerable flexibility and to emphasize those quantities neglected in the elastic theory, thus making it easier to demonstrate their effect upon the bending moments in the truss and on the loads taken by the suspenders. These bending moments and suspender loads have been measured for all types of loading, and compared with values calculated according to both the elastic and deflexion theories, using in each case the value of H, the horizontal component of the cable-tension, derived by the former theory. This comparison makes it possible to determine whether, under such severe conditions of deformation, there is a marked difference between the two methods of analysis, and, further, whether this approximate value of H, used in conjunction with the deflexion theory, gives results in sufficient agreement with those measured.

A new method of arriving at a formula for H has been put forward, and takes into account all deformations of the structure. It consists of finding the equation to the deformed cable-curve after the bridge has been loaded, and equating the length of this curve to that of the cable-curve before loading ; the resulting expression is quite general and applicable to all forms of the suspension-bridge. A further set of calculated bending moments have been obtained for concentrated loads, by the deflexion theory, but using for H this more accurate form. The comparison of these bending moments with the corresponding measured values illustrates the much better agreement resulting from the use of the new formula.

According to the deflexion theory, the rate at which the bending moment at a given point increases is not proportional to the rate of increase of the applied load at any other point or portion of the span. That is to say, the principle of superposition cannot be used. This fact is evident from the exponential form of the equations of the deflexion theory, and the greater the deformation of the structure the greater the error. This phenomenon has also been investigated.

A comparison of the measured values with those calculated according to the elastic theory makes it evident that the method should only be used in the design of bridges having short spans or very stiff trusses. On the other hand, if for the type of bridge under consideration—namely, one of very definite flexibility—the above theory is used to evaluate the bending moments in the truss, the results obtained are much in excess of those measured. This is so whatever the type of loading.

In the case of suspender loads due to concentrated loads, or to loads distributed over a length shorter than the span, the elastic theory gives a maximum suspender load when the loading is centrally placed. In these tests, however, it has been shown that this maximum suspender load occurs when the applied load, or first weight forming the train of loading, reaches the suspender under test. Moreover, the conditions of magnitude noted for the bending moments are here reversed, and the theoretical maximum suspender loads are much less than those observed. In the case of a load distributed over a length greater than the span, however, the elastic theory gives a much better curve, for the maximum suspender loads in this case agree both in position and in magnitude.

With the exception of those quantities measured near the various hinges, the deflexion theory, together with the elastic-theory form of H, gives values of both bending moments and suspender loads which agree quite well with their corresponding measured values. Moreover, if the more exact form of H, that derived in the Paper, is used, the agreement is even better. A full discussion of the exceptions noted above and the factors to which they are due is given in the Paper.

The Paper is accompanied by sixteen sheets of drawings.

Paper No. 5207.

"Curve-Design for Road Improvements."

By JAMES WILLIAM LESLIE BARKER, Assoc. M. Inst. C.E.

(*Ordered by the Council to be published in abstract form* [1].)

EARLY attempts at superelevating curves proved disappointing. Two conclusions based on experience are (1) that camber should be eliminated as far as possible, and (2) that the theoretical amount of superelevation required to permit a speed of 30 miles per hour is often more than that found practicable. A curve of 225 feet radius would require superelevating to the extent of 1 in $8\frac{1}{2}$ at 20 miles per hour, but with a coefficient of friction of 0·25, the same curve, unsuperelevated, may be negotiated at 29 miles per hour. The amount of superelevation, therefore, does not give much guidance to a motorist as to what speed will be suitable or comfortable; guidance is supplied rather by what has been termed "centrifugal sense"[2], seemingly closely connected with the sense of balance. Thus the amount of superelevation cannot be settled by purely theoretical formulas; these methods depend upon a forecast of probable speed, and this is difficult to assess. The amount of superelevation is, in fact, limited by the permissible cross-fall, and the use of certain empirical formulas, tending to conform to this condition, has been found preferable.

Curves designed exclusively as circular arcs in plan are not well suited to the needs of traffic, nor are they to the advantage of the engineer. Such curves define a path other than that which would be followed spontaneously.

Transition-curves enable centrifugal force to be applied gradually, providing also ready means of effecting superelevation within the limits of the curved sections of the road. Improved control will help to avoid accidents, and a transition curve-approximating to the natural path of a vehicle changing direction will facilitate the flow of traffic. Modern congested traffic conditions invest this hypothesis with some importance.

The Author conducted experiments in which a driver and car were encouraged to follow an autogenous path through curves of varying severity. A survey of the nearside track of each of these natural curves was made, and compared with the transition spiral, lemniscate, and cubic-

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[1] The MS. and illustrations may be seen in The Institution Library.—SEC. INST. C.E.

[2] Professor F. G. Royal-Dawson, "Elements of Curve Design." London, 1932; pp. 29, 31, 89, 99, 144, and 149.

parabola curves. A plot of these curves shows the lemniscate to be the nearest to the natural track, although for angles up to, and probably exceeding, 90 degrees, the difference between the lemniscate and spiral curves is very small; in practice it can matter but little which of these is set out. The cubic parabola does not show any similarity to the natural track, except for small deflexion angles. It has been shown [1, 2], that the rate of change of centripetal acceleration should not exceed 1 foot per second per second per second if the motion is to pass unnoticed. Analysis of the natural tracks revealed a rate of change of centripetal acceleration in excess of this standard, but, had the car been restricted to follow the lemniscate curve the desired value would have been practically achieved; in fact the ride would have been more comfortable and, due to the reduced value of the centrifugal ratio, attended by much less danger of sideslip. It seems probable that dangerous values of the centrifugal ratio may be generated, quite unwittingly, on curves of only moderate severity, unless designed on transition-curve principles.

The Author illustrates his theories by an example from actual practice (the Hemel Hempstead road, Watford).

The experiments with natural tracks show that, even at low speeds, vehicles tend to describe transition-curves; junctions should therefore conform to these principles. It will be found, also, especially in restricted situations, that transition-curves have other practical advantages. These curves permit a minor road to enter a major road at any angle between 90 degrees and 70 degrees, and yet maintain almost the same effect as a right-angled junction; furthermore, a bell-mouth is produced sufficiently wide to permit the inclusion of a refuge. Oblique junctions, designed on transition-curve principles, also require the acquisition of less property.

The Paper is accompanied by seven sheets of diagrams.

[1] J. W. Spiller, "High Speed on Railway Curves." Minutes of Proceedings Inst. C.E., vol. clxxvi (1908–9, Part II), p. 75.

[2] W. H. Shortt, "A Practical Method for the Improvement of Existing Railway-Curves." *Ibid.*, p. 97.

"Notes on the Station-Lengthening at Shepherd's Bush Station."

By CLARENCE GEORGE HORATIO FILOR, B.Sc., Stud. Inst. C.E.

THE programme of new work which the London Passenger Transport Board has undertaken includes the lengthening of the Central London Railway and the running of longer trains. All stations on the line have had to be lengthened to accommodate the longer trains. These notes deal with points of special interest in connexion with the work at Shepherd's Bush station.

The Central London Railway is a deep-level system, the tunnels having an internal diameter of 11 feet $8\frac{1}{4}$ inches for the running tunnels and of 21 feet $2\frac{1}{2}$ inches for the station tunnels. A number of crossover tunnels, with an internal diameter of 25 feet, are provided at intervals along the line to allow traffic to be switched from one tunnel to the other.

The usual method of station-lengthening is to extend the separate station tunnels, working outside the running tunnel, so as to cause a minimum of interference with normal train services. The lay-out of the station at Shepherd's Bush made this method of working impossible. Any work at the west end would foul the existing escalators and stairs, and so all work had to be carried out from the east end of the station. There was a 25-foot-internal-diameter crossover tunnel only 70 feet from the station headwall, and the running tunnels rapidly converged from the station tunnels to this crossover tunnel. The new platform had to extend to a point inside this crossover tunnel, and it was therefore decided to use a central, or island, platform. To accommodate this platform, the tracks had to be moved outwards, and this meant increasing the size of the tunnel. As all new work was to be constructed outside the existing tunnels, the new tunnel had to be sufficiently large to give working room outside the 25-foot-internal-diameter tunnel. The new tunnel was, therefore, made 35 feet in internal diameter. As the tracks had to be moved outwards, the new 35-foot-internal-diameter tunnel had to be continued for some distance beyond the end of the new platform.

The 35-foot tunnel was built outside the 11-foot $8\frac{1}{4}$-inch running tunnels until the point was reached at which the tracks would foul the new tunnel. Beyond this point was a length in which the distance between the tracks was such that, whilst they were so close together that two separate station tunnels would foul each other, yet they were too far apart to be accommodated in a single tunnel of reasonable dimensions. The construction used to overcome this difficulty was particularly interesting.

A method of twin-tunnel construction was adopted. This is best describe
as being, in cross-section, two intersecting circles, with the common chor
vertical. This " common chord " was, in fact, a row of steel stanchions
A top capsill girder and bottom capsill girder spanned the stanchions, an
bolted to these girders were cast-iron skewbacks. The twin rings wer
constructed by building segments from the inclined faces of the skewback
in the usual way. The capsill girders were built-up compound girders
3 feet deep. The twin rings were 23 feet 2½ inches in internal diamete
and the centres were 18 feet 4 inches apart. To enable the rings to b
tightened up, steel packing plates and wedges were used between the fac
of the skewback and the segment springing off it.

For a short distance immediately east of the station, the tracks wer
spaced sufficiently far apart to allow separate tunnels to be built. Thus
the extension to the station was to consist of, first two separate 21-foo
2½-inch station tunnels, followed by a length of 23-foot 2½-inch twi
tunnel, and finally a length of 35-foot tunnel.

Train services were not to be disturbed by the new work, and so a
new work had to be constructed outside existing work. From the workin
site, a shaft was sunk, and an access heading driven towards the statio
This heading ran parallel to the existing tunnels, at a level rather abov
the axis-level of the 25-foot-internal-diameter tunnel, and to the nort
side of it. From this heading, a cross-passage was driven to the crown c
the crossover tunnel at a point about half-way along the new 35-foot tunne
From this cross-passage the first four rings of the new tunnel were buil
By starting work half-way along this tunnel, it was possible to work tw
faces, and so to speed up this section of the work.

The access heading continued to meet the back of the existing statio
headwall. From this end of the heading a second cross-passage was drive
to a point between the running tunnels. A 12-foot 5-inch pilot headin
was driven from this cross-passage towards the new 35-foot tunnel.
shaft was sunk from this pilot, and from it a second pilot, 8 feet 6 inches i
internal diameter, was driven, parallel to the top heading. In this botto
heading, a concrete foundation, strengthened with longitudinal joist
was built, and the bottom skewbacks positioned along this foundatio
The bottom capsill girder was bolted to the skewbacks. Shafts were sun
between the top and bottom pilots. In these shafts, the stanchions we
positioned, and bolted down to the girder. The top capsill girder was the
fixed to the stanchions and the skewbacks bolted down to this girder.
was then possible to begin erecting the twin rings. In building thes
rings, each half was erected at the same rate, so as to throw the load upo
the steelwork uniformly, and to avoid distorting the rings As each rin
was built, the wedges were tightened up. Care was taken to tighten u
the wedges of each half of the twin ring together. When any ring wa
thus tightened up, the wedges of rings already built were again tightene
up. Any given ring on a length of girder between two stanchions was onl

considered as finally tightened up when the rings on that length, and on the next length to it, were built. When the whole of the twin tunnel was built, all the wedges were given a final tightening up, the protruding ends were burned off, and the wedges fixed in position by forcing cement grout into the spaces into which the points had been driven.

The lengths of 21-foot $2\frac{1}{2}$-inch station tunnel were built by working from the 23-foot $2\frac{1}{2}$-inch twin tunnels. At this end of the existing west-bound station tunnel, the re-alignment of the tracks involved the re-building of part of this tunnel. To enable this work to be done during normal working hours, a 12-foot-internal-diameter protection-tunnel was built as an extension of the running tunnel, inside the station tunnel. The reconstruction of this part of the station was carried out outside the protection-tunnel.

The completed work consisted of sixty-two rings of 35-foot tunnels, and thirty-one rings of 23-foot $2\frac{1}{2}$-inch twin tunnels. The extension to the east-bound station consisted of ten rings, and, of the west-bound, seventeen rings, whilst the last nineteen rings of the existing west-bound station were reconstructed.

These notes have only dealt with the actual tunnelling work. When the tunnels were built, cross-passages had to be formed between the new 21-foot $2\frac{1}{2}$-inch tunnels. The existing tunnels had to be broken out, the tracks re-aligned, mains and cables diverted, and the actual platforms constructed. The work began in March, 1938, and was finished in September, 1939. The work was designed by Messrs. Mott, Hay, and Anderson, consulting engineers to the London Passenger Transport Board, and the contractors were Messrs. Balfour Beatty and Company, Ltd.

OBITUARY.

JOHN VIPOND DAVIES, son of Andrew and Emily Vipond Davies, was born at Swansea, South Wales, on the 13th October, 1862, and died at Flushing, Long Island, on the 4th October, 1939. He was educated at the Wesleyan College, Taunton, and at London University. In Wales he was engaged in the coal-mining and steel-manufacturing industries until 1889, when he went to New York at the instigation of the late Mr. C. M. Jacobs, with whom he later formed the partnership of Jacobs and Davies. In this earlier association he was employed on the Long Island Railroad during the régime of Mr. Austin Corbin. Later he took up the post of chief assistant engineer of the tunnel under the East River, constructed for the East River Gas Company. During the course of his distinguished career he held many important positions: consulting engineer to the Brooklyn Rapid Transit Company; consulting engineer to the city of Detroit for water-supply and for the tunnel under the Detroit River; consulting engineer for twenty-six aqueduct tunnels in Mexico; one of the board of three engineers responsible for the construction of the Moffat tunnel in the Rocky Mountains near Denver; engineer in charge of the Astoria tunnel for the Consolidated Gas Company of New York; engineer in charge of the construction of the Hales Bar dam across the Tennessee River at Chattanooga; engineer in charge of the construction of the intake and discharge tunnels of the New York Edison Company; one of two engineers engaged on the tunnel- and bridge-crossing of San Francisco Bay. He was engineer in charge of design and construction of the West Virginia Short Line and the Kanawha and Pocahontas Railroads, and of the Atlantic Avenue Improvement of the Long Island Railroad. He was also concerned with the crossing of the Mississippi River at New Orleans.

Amongst his major works were the designing and building (in partnership with Mr. Charles M. Jacobs) of the four tunnels under the Hudson River for the Hudson and Manhattan Railroad, the planning of the Pennsylvania Railroad tunnel under the Hudson and East Rivers. He also designed and supervised the building of the Paris Metro tunnel under the Seine and across the Place de la Concorde.

He was elected a Member of The Institution in 1910, and was awarded the Telford Gold Medal in 1914 for his Paper on "Extensions of the Hudson River Tunnels of the Hudson and Manhattan Railroad Company[1]." He was a Member of the American Society of Civil Engineers, who awarded

[1] Minutes of Proceedings, Inst. C.E., vol. cxcvii (1913–14, Part III), p. 185.

im the Thomas Fitch Rowland Prize in 1917 for his Paper on "The storia Tunnel under the East River for Gas Distribution in New York ity [1]." He was awarded also the Norman Gold Medal in 1913 and the 'owler Professional Award in 1930. He was a member of the American nstitute of Mining Engineers, of the American Institution of Consulting ngineers, and of the United Engineering Society, of which he was president rom 1920 to 1923.

He was a member of the Pilgrims of the United States, the Engineers lub, and the Railroad Club of New York, of which, for many years, he as a member of the Board of Governors; he was also a member of St. eorge's Society, holding the position of President from 1922–1923.

In 1895 Mr Davies married Ruth Ramsey of Pottsville, Pennsylvania, ho died in 1931. They had one son and two daughters.

HARRY JOHN FEREDAY was born at Wednesbury on the 26th ecember, 1862, and died at Epsom, Surrey, on the 20th December, 1939. e was educated at Wolverhampton Grammar School and at the Finsbury nd South-Western technical colleges. In 1880 he became a pupil with e Patent Shaft and Axletree Company, under Mr. Robert Braithwaite, nd assisted in the manufacture of the Dufferin bridge over the river anges, the first all-steel bridge to be sent to India. On the completion f his articles he was appointed assistant manager at the firm's Old Park ridge yard. In 1892 he was appointed assistant engineer in the bridge ard of the Thames Ironworks. In 1896, after a brief period as assistant gineer with Messrs. Crompton and Company, Ltd., of Chelmsford, he tered the service of Messrs. Sir Alexander M. Rendel & Son, and remained ith this firm (now designated Rendel, Palmer, and Tritton) until his tirement in 1937, becoming a partner in 1929. In 1917 he designed his ell-known optical stress-recorder, which has found widespread adoption r the recording of stresses in steel structures under working conditions. e was for long in charge of the firm's steel-bridge department, and was rgely responsible for the design and supervision of many bridges conructed by them in India and other parts of the world, including the husalgarh cantilever bridge over the Indus, the Hardinge bridge over the anges, the Attock bridge over the Indus, and the Willingdon and Howrah idges over the Hooghly. In Africa he was connected with the conruction of the Lower Zambezi bridge. His work in England included e demolition of Waterloo bridge, London, and the reconstruction of elsea bridge, descriptions of which were given in two Papers presented him in collaboration with Mr. E. J. Buckton, M. Inst. C.E. For the

[1] Transactions Am. Soc. C.E., vol. 80 (1916), p. 594.

first of these Papers [1] the Authors were jointly awarded a Telford premiur and the Coopers Hill Memorial Prize, whilst for the second Paper [2] they were awarded a further Telford premium.

He was elected a Member of The Institution in December 1927.

In 1892 he married Elsie, the eldest daughter of Mr. William Henry Bytheway, of Wednesbury, who survives him. There was one son.

JULIAN CLEVELAND SMITH, LL.D., was born at Elmira, N.Y., or the 7th October, 1878, and died at Westmount, Montreal, on the 24th June, 1939. He was educated at the Central High School of Buffalo N.Y., and later at Cornell University, where he obtained the degree o M.E. in 1900. He commenced his business career as draughtsman in the employ of Wallace C. Johnson, consulting engineer, of Niagara Falls, N.Y When, in 1902, Mr. Johnson was appointed engineer of the Shawinigan Water and Power Company plant at Shawinigan Falls, Mr. Smith accompanied him as one of his assistants. In 1903 he was appointed superintendent of the Shawinigan Water and Power Company, and 3 years later was made general superintendent. To those duties were added, in 1909, the duty of chief engineer, and in 1915 he was appointed vice-president. He advanced through the posts of vice-president and managing director until, in 1933, he became president of the firm, a post which he occupied until his death. In addition to heading the parent firm, he was also president or chairman of the board of directors o the subsidiary and associated companies of the Shawinigan Water and Power Company. He also held directorships and vice-presidencies o many other leading concerns. He was always keenly interested in th training and education of youth.

Two Canadian universities recognized his high standing by conferrin on him the degree of LL.D.—Queen's in 1923, and McGill in 1928 He was for many years a Governor of McGill University.

He was elected a Member of The Institution in 1929, and served as Member of Council from 1937 until his death. He was a Member, also of the Institution of Electrical Engineers, the American Institute o Electrical Engineers, and the American Society of Civil Engineers. He wa elected president of the Engineering Institute of Canada in 1928, and wa chairman of the advisory board of the National Research Council o Canada.

Mr. Smith married Bertha Louise Alexander, of New York, in 190 She survives him, together with two sons and two daughters.

[1] Journal Inst. C.E. vol. 3 (1935-36), p. 472 (October 1936).
[2] *Ibid.*, vol. 7 (1937-38), p. 383 (January 1938).

WILLIAM BARTON WORTHINGTON, D.Sc.,B.Sc., was born at Lancaster on the 8th July, 1854, and died at his home at Bushey Heath, Middlesex, on the 29th December, 1939. He was educated at a private school in Lancaster and at Owen's College, Manchester, graduating as B.Sc. in the University of London. In 1923 his services to civil engineering were recognized by Manchester University by the award of the degree of D.Sc. In 1873 he became an articled pupil to his father, Samuel Barton Worthington, M. Inst. C.E., and in 1875 he joined the staff of Messrs. Blyth & Cunningham, of Edinburgh, with whom he was engaged on works for the Caledonian Railway and the reconstruction of the joint station at Carlisle. In 1876 he was appointed resident engineer on new works for the London and North Western Railway in South Lancashire, including the widening of the Liverpool and Manchester Railway from Chat Moss to Manchester and the construction of the Exchange Station, Manchester. In 1883 he became an assistant to his father, whom he succeeded, in 1886, as engineer of the Northern division of the London and North Western Railway. In 1890 he joined the Lancashire and Yorkshire Railway as assistant engineer, and was appointed chief engineer of that railway in 1897. In 1905 he was appointed engineer-in-chief of the Midland Railway, and retained that position until his retirement in 1915, after which he practised as a consulting civil engineer in London.

Dr. Worthington was elected an Associate Member in 1880, and was transferred to the class of Member in 1884. He was a Member of Council from 1907 until his election as Vice-President in 1915.

In 1917 he was elected President, but was prevented by illness from taking office. In 1918 he was again elected Vice-President, and was President during the year 1921–2, following which he served on the Council until November 1927. He took considerable interest in engineering education, and served as President of the Local Associations of Students of the Institution in Manchester and Birmingham. He was also Chairman of the Engineering Joint Council in 1922–3, President of the Smeatonian Society of Civil Engineers in 1928, and a Member of the Institution of Mechanical Engineers since 1897.

In 1888 he presented a Paper entitled "The Permanent Way of some Railways in Germany and in Austria-Hungary," which was printed in volume xcv (1888–89, Part I) of the "Minutes of Proceedings."

In 1883 he married Lilian Broadfield Hughes, who died in 1937.

ABSTRACTS OF THE CURRENT TECHNICAL LITERATURE OF ENGINEERING AND APPLIED SCIENCE.

ENGINEERING CONSTRUCTION.

Stress Functions for a Plate containing Groups of Circular Holes. R. C. J. Howland and R. C. Knight (**Phil. Trans. Roy. Soc.* (A), 238, *357–392 ; Nov. 1939*).—The Authors present a number of solutions of the biharmonic equations, mostly in connexion with the problems of generalized plane stress, when the boundaries consist of circles and straight lines. No numerical work is included, but the expansions of the necessary functions have been determined. They may be used for any problem where the biharmonic equation has to be solved with the appropriate boundaries. The method of solution when the required functions have been established is indicated.

The Phenomenon of Rupture in Solids. (**Ing. Vetensk. Akad. Handl, No. 153, 54 pp ; 1939.*) The Author describes experimental investigations made to verify a statistical theory of the strength of materials and concludes that the rupture in solids may follow two fundamentally divergent courses, resulting in different mathematical expressions for the probability of rupture. He derives formulas and gives tabulated values to facilitate the numerical computation of the distribution constants by arithmetical methods. He also discusses series comprising two or more components, and gives illustrative examples.

Note.—The Paper is in English.

New Methods of Rapid and Economic Construction of Large Underground Works. A. Pettavel (**Gén. Civ.*, 115, *386–389 ; 25 Nov. 1939*).—The article discusses new methods of tunnelling particularly adaptable to the construction of underground works of very large cross section, such as road tunnels, underground railway stations, deep store rooms, etc. These methods consist, in principle, of driving an annular ring, constructing the lining, and working towards the centre. The central rock mass can then be very easily removed. Considerable economies are effected by this method.

Notes.—An asterisk prefixed to a reference, thus **Phil. Trans. Roy. Soc.* denotes that the article is illustrated.

The abbreviated titles of periodicals are those used in the " World List of Scientific Periodicals " (Oxford 1934).

The Technique of Tri-Axial Compression Tests. J. D. WATSON *Civil Engg., N.Y.*, 9, *731–733; Dec. 1939*).—The type of apparatus lescribed was developed by the Author for testing cohesionless soils in onnexion with the design of the dam at Franklin Falls, N.H. The vorking fluid used is glycerine. The technique of testing is explained, and ypical results are shown by means of curves, which are briefly analysed.

A High Water-Tower of Large Capacity. A. POTTER and M. H. LEGERMAN (**Engng. News-Rec.*, 123, *700–702; 23 Nov. 1939*).—This steel ank and tower, completed in July, 1939, for the city of Batavia, N.Y., has diameter of 103 feet and a water-depth of 25 feet, with a capacity of ,500,000 gallons. The height of the structure to the high-water level is 69 feet. The Authors describe the studies made for the foundation supports, the arrangement of the columns, and the wind-bracing, and discuss he design of the central riser pipe, 10 feet in diameter, which serves as a olumn, the plates being subjected to a heavy vertical load.

A New Pier Design for Deep Overburden. E. E. HOWARD (**Engng. News-Rec.*, 123, *687–688; 23 Nov. 1939*).—In order to avoid costly pneuatic work in the construction of the foundations of the new bridge over he Missouri river at Brownville, Nebraska, a novel procedure was adopted. win cylinders of sheet-piles, each pile having a steel bearing pile riveted o it, were driven to bedrock, enclosing cores of the overburden. The aterial inside the cylinders was excavated to below the scour-plane and as replaced by plugs of concrete. Over all, spanning and enclosing the ops of both cylinders, was placed a concrete cap, from which the piershafts are being built up. The cost is stated to be 18 per cent. lower than r pneumatic caissons.

Bridge and Tunnel Approaches. J. F. CURTIN (**Proc. Amer. Soc. iv. Engrs.*, 65, *1527–1551; Nov. 1939*).—The Author states that although 5-50 per cent. of the cost of vehicular bridges and tunnels is expended on eir approaches, but little information in regard to research or analysis as been rendered available to the engineering profession. He reviews the ore significant elements of bridge and tunnel approaches, and compares the lative merits and disadvantages of various types of approaches. He onsiders the design of bridge and tunnel plazas, upon the basis of their nctions of toll-collection and the convergence of traffic-lanes, and discusses ecentralized plazas, reservoir-space, the layout of plazas, and portal ansitions. Examples of approaches in several large American cities are ustrated.

The Meeker Avenue Bridge, New York. N. DEUTSCHMAN (**Engng. ews-Rec.*, 123, *706–709; 23 Nov. 1939*).—The bridge is 6,415 feet in ngth, but only 300 feet, the high-level span over Newtown Creek, crosses

water. Exceptional constructional problems were involved near the foundations for the river span, where a highly-acid soil necessitated special protective work, and in the erection of steelwork over a waterway the full width of which had to be kept clear for navigation. The bridge provides two roadways, each 32 feet wide, flanked by two 8-foot footways. The cost, including $606,720 for land, is $5,588,582.

The Bascule Railway-Bridge over the South Beveland Canal near Vlake, Holland. T. W. MUNDT (**Bull. Int. Rly. Cong. Ass.* (*English Edition*), 21, *1031–1047 ; Nov. 1939*).—The importance of the traffic on the South Beveland canal made it necessary for the swing bridge near Vlake to be replaced by a high-level opening bridge. The bascule type was selected, and twin single-track spans were provided, coupled together, and placed alongside a bascule road-bridge. Details of the design and construction of the bridge are given, with particulars of the operating gear.

The Strength of Struts having Ends elastically Direction-Restrained. H. A. WARREN (**Structural Engr.*, 17, *445–468 ; Dec. 1939*).—The Author extends the usual Eulerian theory to struts having elastic end restraint, and derives values of the effective length-ratio for use in the more usual strut formulas. He also demonstrates the elastic restraint provided by various members framing into the stanchion. The usual analysis for struts with initial curvature, and eccentricity of loading, are extended for elastic conditions, and are used as a basis for a simple rational formula by which the safe load on any strut can be calculated. Several numerical examples are worked and compared with the results given by existing formulas.

A Point-Supported Dome of the Thin Shell Type. ANTON TEDESKO (**Engng. News-Rec.*, 123, *767–768 ; 7 Dec. 1939*).—The new McAlister auditorium at Tulane University, New Orleans, consists of a circular central unit 110 feet in diameter, adjoined by structures rectangular in plan incorporating the stage, side wings, and balconies. The roof of the central hall could not be supported continuously along its circular base ring because the number of columns was restricted by the design requirement for a minimum column-spacing of 54 feet for the stage and balcony openings. Instead of a conventional dome supported on steel trusses or girders and beams, it was decided to adopt a monolithic concrete dome of the thin curved-slab type, the slab providing the " girders " to support itself as well as suspended loads for projector-rooms, ventilating-ducts, and adjoining roofs. The necessary stiffening at the springing-line is provided by a polygonal set of diaphragms.

Completion of Baker Street–Finchley Road Loop (Bakerloo Line), London. (**Rly. Gazette* (*Lond.*), 71, *668–675 ; 24 Nov. 1939.*)—The opening, on the 20th November, 1939, of the new loop from Baker Street

(Bakerloo line) to Finchley Road (Metropolitan line) enables Bakerloo trains to run to and from Stanmore. The work included the driving of $4\frac{1}{2}$ track miles of tube (single-line) and the necessary junctions at each end, and two new stations. Many alterations to existing works were also necessary between Finchley Road and Wembley Park.

Raising the Tracks of the Central Railroad of New Jersey to eliminate Level Crossings and Street Crossings at Elizabethport, N.J. (**Rly. Age*, 107, *784–788 ; 18 Nov. 1939.*)—The work comprised the elevation on embankments of two intersecting lines (one of four tracks, the other single) connected by four spurs to enable transfer moves to be made in all directions. There were many street crossings, and the work had to be done under traffic, whilst about thirty shifts of traffic from one set of tracks to another had to be made. The work cost about $5,000,000.

Signalling on the Municipal Bridge at St. Louis, Mo. (**Rly. Signaling*, 32, *595–600 ; Nov. 1939.*)—A description is given of the signalling equipment on the Municipal bridge connecting East St. Louis, Ill., and St. Louis, Mo., and on its six double-track approaches. Two signal-cabins are provided, containing relay-interlocking equipment controlled by knobs on the cabin diagrams. Multiple-aspect colour-light signalling is employed.

Steel Sheet-Pile Wharf at Rimouski, Quebec. J. P. CARRIERE (**Civ. Engng., N.Y.*, 9, *707–710 ; Dec. 1939*).—The Author discusses the conditions existing at Rimouski, which is situated on the St. Lawrence river, 180 miles downstream from the city of Quebec, and is the only river port below Quebec with accommodation for ocean-going steamers. The new works will add 3,680 linear feet of berthing-space when completed. He describes the preliminary foundation tests, and the method by which the driving-time required for 1,500 main piles was predicted from the data obtained on a single test-pile, with an error of only 4 per cent. He also describes the design of the pier, and the constructional methods adopted.

The Albert Canal, Belgium. (**Ossature Métall.*, 8, *459–507 ; Nov. 1939.*)—In a series of five articles descriptions are given of various works on the canal, which connects the river Meuse, at Liège, with the Scheldt at Antwerp, and has a length of 129 kilometres (90 miles), in the course of which it is crossed by sixty-six bridges. Mr. G. DE CUYPER (*pp. 465–473*) describes the metal bridges ; the characteristics of the principal bridges are dealt with in *pp. 475–488* ; Mr. H. N. F. SANTILMAN (*pp. 489–498*) describes the principal hydraulic works ; the locks are described in *pp. 499–505* ; and brief descriptions of the coaling-stations at Genk, Zolder, and Beringen are given on *pp. 506–507.*

Water-Hammer Studies on Long Pipe-Lines. L. E. Goit (**J. Amer Waterw. Ass.*, 31, *1893–1903 ; Nov. 1939*).—The Author describes test made on some of the longest pipe-lines in Los Angeles, Cal., with the object of checking water-hammer effects in large pipe-lines against the results o studies made on smaller lines ; of determining the effects of rate of chang of velocity upon surge-pressures ; of determining the effects of the rate o valve-closure upon the rate of change of velocity and upon surge-pressures and of determining the hydraulic characteristics of valves. Results ar plotted in curves, and the Author concludes that the time of shut-off of a long pipe-line can be reduced considerably by proper design and operatio of valves, and that the resulting pressure-rise can be restricted within saf limits.

Water-Hammer Control by Proper Valve-Installation. E. C Brisbane (**J. Amer. Waterw. Ass.*, 31, *1904–1908 ; Nov. 1939*).—The Author observes that no valve of present-day design embodies all the features necessary for perfect control of pipe-lines. He discussses the effects of water-hammer and the necessity for the provision of valves at points facilitating isolation of the line at hazardous places and in the least possible time. Factors which form an essential part of valve design are (1) the characteristic of the valve with relation to the percentage of area-reduction in comparison with time and stroke ; (2) the operating torque necessary to overcome the hydraulic unbalance plus the mechanical or sliding friction, and the operating torque correlated with time.

Effects of Rifling on 4-inch Pipe transporting Solids. G. W. Howard (**Proc. Amer. Soc. Civ. Engrs.*, 65, *1591–1603 ; Nov. 1939*).—The tests described were made at the U.S. Waterways Experiment Station, Vicksburg, Miss., and the results were compared with those from 2-inch pipe, in order to ascertain whether any similarity appeared between the characteristics of each pipe, so that the principle of these smaller pipes could be applied to larger sizes. Most of the tests were made with sand as the transported material, but the rifling was also tested later with silt, clay, and pea gravel. The Author concludes that rifling will improve the efficiency of the pipe-line when coarse sand or gravel is transported ; but will reduce it when silt or clay is transported. He states that rifling in the discharge line of a dredger will increase the efficiency of the line in cases wherein the material being dredged through a plain pipe would settle along the bottom in appreciable quantities.

Stresses and Strains in a Special Type of Metallic Sheath. A. Dumas (**Bull. Tech. Suisse Rom.*, 65, *293–297, 305–309 ; 18 Nov. and 2 Dec., 1939*).—A special type of Y-shaped metallic pipe-joint sheathing, with reinforcing fins, has been the subject of exhaustive pressure tests at the University of Lausanne. The mathematical theory arising from the results

of these tests is expounded at length and many descriptive diagrams are presented. Special attention has been given to the conditions existing at the crutch of the Y and in the reinforcing ribs.

Extension of the Lungernsee Electricity Works, Switzerland. (**Schweiz. Bauztg.*, **114**, *243–251 ; 18 Nov. 1939*.)—Detailed descriptions of the works were published in 1924 (ENGNG. ABSTRACTS, **52**, *No. 134 ; Oct. 1925*) and 1926 (*Schweiz. Bauztg.*, **87**, *193*). The output has now been increased to 84,000 horsepower. A review is made of the various stages in the development and deepening of the lake. On *pp. 246–249* Dr. L. BENDEL discusses the movements of the lake shore, and the regulating works. On *pp. 249–50* the hydraulic machinery for the present extension is described by Mr. E. HABLÜTZEL, and on *pp. 250–251* the construction of the Grosser Melchaa pressure-tunnel is discussed.

MECHANICAL ENGINEERING.

Some Factors affecting the Form of Condensation of Steam. C. L. OLD (**J. & Proc. Instn. Mech. Engrs.*, **142** (*Journal 199–200*) *; Dec. 1939*). —The Author describes investigations made at the Manchester Municipal College of Technology, upon various metal surfaces. He discusses the preparation of the surface, the presence of contaminants, the ageing of the surface, the effects of the presence of non-condensable gases, of the temperature of the plate, and of the roughness of the surface, surface-tension, the rate of flow and the quality of the steam, and viscosity.

Some Problems in the Operation and Maintenance of Steam Boiler Plant. F. J. REDMAN and H. A. J. McDONIC (**J. S. Afr. Instn. Engrs.*, **38**, *150–185 ; Dec. 1939*).—The Authors review the development of the power-stations operated by the Victoria Falls and Transvaal Power Company, Ltd., and describe in detail the plant installed at the Witbank and Klep stations. They discuss factors affecting operation, including furnace-arches, grit-liberation, the effect of modifying stoker-hopper design and primary air distribution, fan erosion, modern furnace design and operation, and air-preheaters. Data in regard to plant characteristics and operating results are presented in numerous Tables.

Piston and Piston-Ring Temperatures. P. V. KEYSER, jun., and E. F. MILLER (**J. Inst. Petroleum*, **25**, *779–790 ; Dec. 1939*).—The increase in the specific output of internal-combustion engines during recent years has given rise to problems of lubrication, especially in view of the excessive piston-temperatures which develop in the piston-ring zone. The Authors discuss piston deposits, methods of measuring piston temperature, and the measurement of cylinder-wall temperatures. They describe laboratory experiments, and consider the effect of design upon piston temperature.

New Locomotives for India. (**Rly. Gazette* (*Lond.*), 71, *704–708; 1 Dec. 1939.*)—Particulars are given of the five new designs adopted by the Indian Railway Board for use on the North Western, East Indian, and Great Indian Peninsula Railways. The designs comprise a 4–6–2 tender engine (class WL), and 2–6–4, 2–4–2, 2–6–2, and 0–6–2 tank engines (class WM, WU, WV, and WW, respectively). The first engines of the WV class have already been completed in England.

Electric Locomotives for the New Zealand Government Railways. (**Commonwealth Engineer*, 27, *94–97; 2 Oct. 1939.*)—Seven locomotives of the 1–D_0–2 type are in course of delivery to the New Zealand Government Railways, which are of 3-foot 6-inch gauge. The locomotives are designed to haul 250-ton passenger trains at speeds of up to 55 miles per hour, and 500-ton freight trains at up to 45 miles per hour, over the Wellington-Paekakariki section (25 miles long, with a ruling gradient of 1 in 57). The line is electrified on the 1,500-volt direct-current system. The traction-motors are arranged on the series-parallel system with two pairs in permanent series. Unit-switch electro-pneumatic control equipment is fitted. The locomotives weigh 88 tons in working order, and can exert a maximum tractive effort of 34,000 lb.

Railcar Air Resistance. (**Rly. Gazette* (*Diesel Rly. Traction No. 91*), *192–199; 22 Dec. 1939.*)—A description is given of the calculations and test results obtained from a type of standard-gauge bogie car designed for speeds of from 60 to 75 miles per hour, and having a smooth but not truly aerodynamical contour. The results are plotted in a series of Tables and curves.

New Great Western Railcars. (**Rly. Gazette* (*Diesel Rly. Traction No. 91*), *188–189; 22 December 1939.*)—Twenty new cars are under construction, fitted with buffing- and draw-gear and equipped for multiple-unit operation. Four cars are to be arranged as two twin-car units, gangwayed together. Two six-cylinder direct-injection diesel engines are fitted to each car, one on each side, and each drives the two axles of one bogie through a fluid flywheel, epicyclic gearbox, and cardan shaft; the reversing gear is incorporated in the bevel drive to the inner axle of the bogie, and the outer axle is driven through bevel gears from the reversing gearbox. Five speed-ratios are provided.

Modern Engineering as it affects Rolling-Mill Practice and Design. E. T. Judge (*Proc. Cleveland Instn. Engrs., 1938–9, 183–200; 1939*).—The Author discusses the subject under the headings of rolling, finishing, and services. He deals in detail with mill housings, the rapid changing of rolls, mill guides and mill bearings, and electric drives. He describes the

finishing processes, including heat-treatment, and reviews the development of electrical power-supply to rolling-mills, the progress of mill lubrication, de-scaling equipment, and the preparation of rolls.

A Fabricated-Steel Cement-Grinding Tube Mill. (**Engineering*, 148, *681–682 ; 22 Dec. 1939.*)—Constructional details are given of a large compound tube mill recently installed at an Essex cement plant. The mill has a tube 7 feet 3 inches in diameter by 39 feet in length, and runs at 19 revolutions per minute continuously throughout a 24-hour day. Completely welded fabrication was adopted, the shell being made of mild-steel boiler-plate, $1\frac{1}{8}$ inch thick ; three plates were used in the length ; thus there are only two circumferential seams and three longitudinal seams. Details of lubrication and of the electric drive are given.

Flame-Hardening of Large Lathe Parts. (**Machinist*, 83, *849–851 ; 25 Nov. 1939.*)—A number of 44,000-lb. driving-head spools for a group of boring-machines were required to have a hardened surface of from 350 to 500 Brinell number, free from checks, cracks, and chatter-marks, whilst retaining the maximum toughness of the core material. The problem was solved by applying the oxy-acetylene process of flame-hardening, which provided a flexible method by which the specifications of the contract could be met with the minimum expenditure for hardening equipment. The spools were each made of two forgings, and each forging weighed approximately 22,000 lb., having an inside diameter of 51 inches, an outside diameter of 63 inches, and an overall length of 48 inches. At one end was an 8-inch flange, 88 inches in diameter. The equipment for hardening the spools, and the technique adopted as the result of model-tests, are described in detail.

Burning during Welding of Mild-Steel Sheet. T. Swinden and H. Sutton (*Trans. Inst. Welding*, 2, *187–189 ; Oct. 1939*).—During the gas welding of mild-steel sheets manufactured to British Standard Specification No. 353, it was found that the welds exhibited a frothy or burned appearance on the underside, particularly where penetration had been complete. Microscopical examination of the welds revealed porosity in the form of blow-holes, and also oxide-inclusions. The results of chemical analyses, including determinations of oxygen, hydrogen, and nitrogen, suggest that the tendency to burning is influenced by the content of residual elements in the steel (which increases the tendency), and by the content of silicon (which decreases it). In general, steels of high silicon-content exhibited good gas-welding properties.

Endurance Tests on Special Joints with Heat-Treated or Machined Welds. Hugh O'Neill and F. C. Johansen (**Trans Inst. Welding*, 2, *222–225 ; Oct. 1939*).—The Authors describe tests carried out on low-

alloy-steel fillet welds subjected to strictly-localized heat-treatment. The object of the experiments was to determine the change in resistance to reversed stresses at room temperature of a two-row riveted lap joint in 2-per-cent. nickel steel, after (*a*) applying a sealing run of weld-metal; (*b*) tempering this sealing run with a blowpipe; or (*c*) grinding the surface of the weld fillet. The Authors conclude that local heat-treatment, by blowpipe, of hard fillet welds causes a decrease in the endurance value of the joint, and that surface grinding of the weld-bead to produce a smoothly-surfaced well-shaped fillet improves the fatigue resistance.

Modern Methods in the Design and Manufacture of an 80-ton Gantry Crane. (**J. Amer. Weld. Soc.*, 18, *706–709; Nov. 1939.*)—The crane described is an electrically-operated gantry, having a double-drum main hoist of 80 tons lifting capacity, mounted on a trolley of conventional overhead-crane type, supported by a gantry bridge, which is equipped with four two-wheel trucks for moving the bridge along rails on the dock at the site of the Pickwick Landing dam, Tennessee. Approximately 80 per cent. of those parts which formerly would have been made of cast steel or cast iron were made of welded steel. The design is described and general notes on fabrication are given, with a statement of costs for welded structural and machinery parts in comparison with the costs of castings, indicating a saving of about 15 per cent. in favour of welding.

A Ship-Loading Ropeway. (**Engineer, Lond.*, 168, *572–573; 8 Dec. 1939.*)—A bi-cable plant for loading ships with pyrites has recently been placed in service on the south coast of Cyprus, in conjunction with a large storage-area from which loading of the ropeway buckets is effected. The initial capacity of the ropeway is 100 tons per hour, whilst its ultimate capacity, when further buckets are introduced, will be 200 tons per hour; its length is more than 1,800 feet. The track ropes on the "full" side are of the locked-coil type, of $6\frac{1}{2}$ inches circumference, and on the "empty" side of 4 inches circumference. The Lang-lay hauling-rope is $2\frac{3}{8}$ inches in circumference, and is driven by a 30-horsepower motor. In order to accommodate the varying heights of vessels, the main shoot has hinged to its end a shorter jib, which lengthens the shoot by about 16 feet. The shoot can be slewed 60 degrees either side of the centre-line.

The Horizontal Carriage of Granular Material by an Injector-Driven Air-Stream. S. A. Wood and A. Bailey (**J. & Proc. Instn. Mech. Engrs.*, 142 (*Proc. 149–164*); *Dec. 1939*).—The Authors describe tests made with an experimental horizontal conveyor, using sand and linseed as the materials conveyed. The results indicate that there is a definite optimum position for the injector in the pipe-line, and that it is advan-

tageous to use a divergent diffuser at the outlet end. Observations show that the path of a grain consists of a series of leaps, the length of which increases with the grain-speed.

The Behaviour of Various Engine and Gear Lubricants in Seizure Tests. D. Clayton (**J. Inst. Petroleum*, 25, *709–728; Nov. 1939*).—The Author describes an investigation of the effect of various lubricants upon the seizure characteristics of hard steel in the four-ball apparatus. It was found that ordinary lubricants, as well as extreme-pressure lubricants, yield significant results. Tests were made with commercial engine oils, two extreme-pressure lubricants, a mineral oil, kerosine, and petrol. The Author discusses the applicability of the results to gear-lubrication.

Engineering Services at an Extended Factory. (**Power & Works Engr.*, 34, *431–436; Nov. 1939.*)—A detailed description is given of the new boilers and ancillary plant for heating, ventilating, and other services installed in a factory extension intended to dovetail with the existing factory and its production-flow, whilst also being capable of functioning as a separate entity. The requirements were threefold. Steam is needed at a relatively high pressure for processes in the factory, and at a lower pressure for space-heating by means of unit heaters, whilst it is also employed to provide hot water through the agency of calorifiers. A large proportion of the steam is used for space-heating, the demand for which is seasonal, and it was therefore inexpedient to install pass-out or back-pressure power-units for carrying the electrical load of the factory. Two new boilers of the super-economic type were installed, each with a capacity of 12,500 lb. of steam per hour at 100 lb. per square inch. Descriptions are given of the boilers and auxiliary plant, and of the new ventilating, compressed-air, and electrical equipment.

The Thermal Manometer, a New Device for Recording Low Absolute Pressures. R. S. Vincent and A. Simons (**Proc. Phys. Soc.*, 51, *1003–1009; 1 Nov. 1939*).—The Authors describe an instrument for recording absolute pressures in gaseous media over the range from 0·1 millimetre to 100 millimetres of mercury. This consists of a tall glass tube about 1 inch in diameter closed at the bottom and with a side tube at the top for connecting to the pressure to be measured. A narrow tube, also sealed at the bottom, runs down the centre of the wide tube to within about 3 inches of the bottom. A small quantity of mercury is kept boiling by an external heater in the bottom of the larger tube. The vapour condenses on the side of the tube, and the condensation temperature is recorded by a thermocouple passed down to the lower end of the inner tube. The heat-supply is arranged so that the mercury is just boiling at the highest pressure which it is desired to measure. At low pressures the mercury boils faster and the vapour condenses right up the wall of the tube nearly to the top. The results obtained are plotted in curves.

The Relationship between the Mechanical Properties of Materials and the Liability for Failure in Service. L. W. Schuster (**Bull. Liverpool Engng. Soc.*, 13, *11–47 ; Nov. 1939*).—The Author observes that the usual failure is due to faulty design or workmanship, carelessness in operation, or such causes as torsional or other form of vibration. Tests such as are called for in purchasing specifications are very deficient as a means of giving information that is really useful in judging the relative suitability of different materials for service. He analyses the various types of tests—tensile, bending, and torsional—and discusses the effects of overheating the material. He concludes that when service breakages under dynamic loading are caused by some inferior mechanical property, the inferiority must be sought in some property not usually measured in a test-house.

MINING ENGINEERING.

Rock-bursts in the Kirkland Lake Area. J. D. Christian (*Canad. Min. & Metallurg. Bull. No. 331, Nov. 1939, pp. 550–567*).—In a report prepared for the Kirkland Lake Mine Operator's Rock-burst Research Committee, the Author describes the results of attempts made to control ground-pressure at the Teck-Hughes gold mines. The mine records indicate that comparatively few of the bumps registered on surface and underground manifest themselves by failure of rock exposed in the mine workings. The Author suggests that the shocks must originate from movements deep in the walls of the evacuated spaces, and advances evidence of this. Such movement would be possible only under the theory of doming, the fundamental principle of which seems to be supported by experience at the Teck-Hughes mines. Descriptions are given of typical bursts, discriminating between strain bursts, pillar bursts, and crush bursts. Stress is now laid upon the sequence and method of mining, whilst packing is regarded as of secondary importance. Diamond drilling of shot-holes has been recognized as the safest means of recovering pillars.

The Control of Mine Roadways. D. W. Phillips (**Colliery Guard.* 159, *864–866 ; 15 Dec. 1939*).—The Author cites his earlier work (Engng Abstracts (*Min.*), 2, *No. 8, 1 Jan. 1939*), and describes further confirmatory tests made on two conveyor gate roads. He states that the results obtained on the two roadways supported by double packing are equally as good as those previously reported, and that the saving in material and labour was about £2 10*s*. per yard, totalling £5,400.

Pneumatic Picks in the Blackshale Seam. (**Iron Coal Tr. Rev.*, 139 *646, 648 ; 10 Nov. 1939.*)—After a description of the use of packs to reduce shot-firing at the Markham collieries, mention is made of a recently introduced silencer. The silencing effect is obtained by means of an asbestos pad which is fitted around the cylinder exhaust-ports. A piece of fine

mesh copper gauze is fitted over the asbestos and maintained in position with a copper clip. The handle of the pick, when screwed into position, forms a totally enclosed and mistake-proof exhaust-silencing device, with a negligible increase in the weight of the machine.

Roof-Behaviour on Machine-Cut Coal-Faces. (**Trans. Instn. Min. Engrs.*, 98, *114–146 ; Dec. 1939.*)—This Paper is the tenth progress report of the Safe Working in Mines Committee of the Midland Institute of Mining Engineers. In order to obtain further information as to the influence of modern methods of working upon the behaviour and state of the roof at the coal-face, the working of machine-cut faces in several Yorkshire seams has been observed over long periods, and the Committee has studied the relationships between roof behaviour, the depth of the undercut, and the methods of roof-control in various natural conditions. It has now been rendered clear that although roof-movement is continuous, the dominant factors vary at different times in the cycle, and that for practical purposes (where floor-lift is negligible) normal convergence may be considered to be the result of two separate effects: namely, a roof-displacement occurring during the periods of acceleration and retardation (the " cutting effect "), and a displacement occurring during the period of steady lowering. The rate of steady lowering before and after cutting varies with the effectiveness of the roof-control. Summarized conclusions are presented in the Report.

Dust in British Columbia Mines. D. A. MacLeod (**Canad. Min. & Metall. Bull. No. 330, pp. 427–434 ; Oct. 1939*).—The production of dust and the measures to be taken for its prevention have formed the subject of investigation in British Columbia for over a year. The Author discusses the most important aspects of the dust problem, and recommends methods for its suppression and elimination. It has been recognized that the principal source of dust underground is shot-firing, and also that the most effective means of decontaminating the mine atmosphere is liberal ventilation of all working places. Attention should be given to the type of machine used for drilling operations. Atomizers or water-blasts should be used in conjunction with shot-firing, and water should be freely applied to all broken rock. Working hours should be arranged to prevent workmen from being exposed to dust from blasting. Unless absolutely necessary, secondary shot-holes should not be fired during the shift. Respirators should be worn to provide partial protection in places where no effective measures can betaken to eliminate dust.

Winding-ropes. H. Herbst (**Kohle u. Erz*, 36, *592–596, 609–611 ; 619–622 ; 5 and 19 Oct. ; 2 Nov. 1939*).—The Author observes that for some years past the number of fractures observed in main winding-ropes has increased. Usually these fractures are first discovered when an outer wire breaks. and an examination usually reveals that underneath

several of the inner wires are also broken. Fractures of the inner strands not observable from the outside can be detected by electromagnetic measurements. He discusses working conditions and the construction of various types of wire ropes, and describes tests on main winding-ropes and staple-shaft winding-ropes which have fractured under various conditions of operation.

A Modern Coke-Oven and By-Product Plant. James Ritchie (**Min. Elect. Engr.*, 20, *181–186 ; Dec. 1939*).—The plant, installed in the Glasgow district, consists of fifty underjet regenerative ovens, capable of producing 500 tons of blast-furnace coke per day, with machinery for coal- and coke-handling and the recovery of by-products. Details are given of the piling foundations for the heavier structures, of the coal-crushing and oven-service machinery, of the electrical equipment, and of the coke-conveyors.

Dust produced by Drilling when Water is sprayed on the Outside of the Drill-Steel. J. A. Johnson and W. G. Agnew (**Rept. Infmn. U.S. Bur. Min., No. 3478, 6 pp. ; Oct. 1939*).—The Authors describe tests conducted at the Mount Weather testing adit to determine the effectiveness of spraying water along the outside of the drill-steel, in comparison with standard wet-drilling practice. The spray equipment was designed primarily for the control of dust from dry drilling with solid-type drill-steel in quarries. The results show conclusively that spraying water along the outside of the drill-steel should not take the place of wet drilling underground. Even if a method be devised for use in holes at an inclination above the horizontal, far too much dust is disseminated even to consider its use in place of wet drilling. It might prove to be a valuable accessory to regular wet drilling in collaring and drilling the first 2 feet of a hole. Tests indicate that the greatest quantity of dust is thrown into the air in drilling the first 2 feet of a hole. When the spray was used with a slow cutting-machine, such as the quarry plug drill, the device restricted the dust disseminated within limits that are considered good underground practice.

Combating Mine Fires in the Ruhr district. E. Bredenbruch (**Glückauf*, 75, *781–786 ; 16 Sept. 1939*).—In this description of the manner in which mine fires are dealt with in the Ruhr coal-mines, a distinction is made between " open " fires and " seam " fires. Since open fires occurring in roads, engine-rooms, and pumping-stations spread rapidly unless dealt with at their source, the installation of automatic sprinklers is recommended. In discussing seam fires (goaf fires and fires in old workings), the process of spontaneous combustion and the conditions leading up to it are examined, and methods of fighting seam fires by direct action at their source, and by sealing the involved area by means of stoppings, are discussed. The practices adopted in building fire-stoppings are described.

Removal of Nitrous Fumes from Mine Air. H. C. Dod (**Chem. Engng. Min. Rev.*, 31, *494–495 ; 10 Sept. 1939*).—In reporting the results of nvestigations on mine ventilation to the Mine Safety Committee in Kal-;oorlie, W. Australia, the Author referred to the use of ammonia for neutral-zing nitrous fumes generated by explosives. Chemicals liberating free .mmonia are made up in the compact form of a small cylinder which is nserted between two cartridges of the charged hole. Experiments had hown that certain metallic oxides would accelerate the reaction. Mag-iesium was adopted for this purpose. The nitrous fumes (NO_2) combine vith the ammonia to form the nitrate and nitrite of ammonia. The xplosion of the charge causes the cylinder to be blown to fragments and he ammonium salts to disintegrate into free ammonia and certain acid adicals, which subsequently combine with the incorporated metallic salts, nd take no further part in the process. Owing to the temperature being oo low for them to dissociate, the nitrate and nitrite of ammonia fall to he ground. The numerous experiments that have been carried out have hown by actual qualitative analysis that NO_2 is removed by the use of he gas-generating cylinders. Miners who have used them report that he resultant atmosphere is pure and fresh in comparison with that xperienced after normal shot-firing.

Excessive Heating in Motor Leads. C. H. S. Tupholme (**Min. Mag. ond.*, 61, *275–278 ; Nov. 1939*).—The Author discusses the characteristic eatures of protective devices for the prevention of dangerous overheating ı electric circuits underground, and the factors to be borne in mind when ıstalling such devices. He considers that fuses form the most reliable rotection abainst short-circuit, whilst thermal protective switches placed ehind heavy-current fuses provide effective protection against ordinary ervice overloads. It is simpler for the installation, and also for service, hen a properly-dimensioned main fuse is used for a whole set of switch-oxes.

Control and Automatic Protective Devices for Electrical Power nderground. F. Kesselring (**Glückauf*, 75, *817–823 ; 7 Oct. 1939*). -The Author describes protective devices for electrical installations under-ound, including high-power switches, protection for transformers, low-ower switches, and methods of exercising control over low-voltage distri-ıtion circuits and electrically-operated machinery. He discusses in tail the development of switches using water as the arc-quenching edium. In studying the generation of gas in a switch of this type an teresting phenomenon was observed. In the intense heat of the arc, ıich may amount to 17,000° C., the water in the immediate vicinity of e arc is decomposed into hydrogen and oxygen ; hence knall gas should formed ; but experiments failed to reveal the presence of this gas. A oser investigation disclosed the fact that in the cooler parts of the cham-

ber, that is to say, away from the arc, hydrogen and oxygen enter into slo[w] combustion to form water again, and are consequently not found separat[e] after the experiment. By adopting a design favourable to this recombina[-]tion, it is possible to construct expansion-chambers in which practically n[o] gas-evolution occurs.

Note.—The Institution as a body is not responsible either for th[e] statements made, or for the opinions expressed, in the Papers an[d] Abstracts published.

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NOTICES

No. 4, 1939—40

FEBRUARY, 1940.

MEETINGS, SESSION 1939–40.

ORDINARY MEETINGS.

Ordinary Meetings will be resumed from the 20th February, and the following subjects will be brought forward for discussion :—

1940.
(5.30 p.m.)

Feb. 20. **"The Dragline Excavator."** W. Barnes.

Mar. 19. **"The Sewage Disposal of Delhi."** J. A. R. Bromage, M. Inst. C.E.

Apr. 23. **"Remodelling of the Assiut Barrage, Egypt."** J. E. Bostock, O.B.E., M. Inst. C.E.

May 14. **"Cliff-Stabilization Works in London Clay."** J. Duvivier, B.Sc. (Eng.), M. Inst. C.E.

Brief Abstracts of these Papers appear on pp. [15] *et seq.*

VERNON-HARCOURT LECTURE.

The Vernon-Harcourt Lecture on "The Construction of Deep-Water Quays" will be delivered by Mr. A. C. Gardner, M. Inst. C.E., on Tuesday, March, at 5.30 p.m.

INFORMAL MEETING.

Date.

Mar. 11. "Emergency Repairs, with Special Reference to Welding."
(6.0 p.m.) (Jointly with the Institutions of Mechanical and Electrical Engineers at the Inst. E.E., Savoy Place, Victoria Embankment, W.C.2.)

ROAD ENGINEERING SECTION.

Apr. 2. "The Engineer's Part in the Promotion of Road Safety", by F. A.
(5.30 p.m.) Rayfield, Assoc. M. Inst. C.E.
(At the Inst. C.E.)

JAMES FORREST LECTURE.

The James Forrest Lecture will be delivered by Mr. E. V. Appleton, M.A., D.Sc., LL.D., F.R.S., on Tuesday, 28 May, at 5.30 p.m.

ANNUAL GENERAL MEETING.

The Council, acting on the powers conferred upon them (see p. 4), have decided that the Session shall end on the 30th May, and that the Annual General Meeting shall be held on the 11th June at 5.30 p.m., unless otherwise announced.

SPECIAL ANNOUNCEMENTS.

ARMY OFFICERS' EMERGENCY RESERVE.

Corporate members are informed that registration in the Army Officers' Emergency Reserve has now been resumed so far as Civil Engineers are concerned, and members who desire to apply for registration, and who are free to do so, may obtain the necessary form of application from the Secretary. After the form is completed it should be returned to the Institution, when a certificate of membership will be attached to it and the application will be transmitted to the War Office.

It should be noted that the Army Officers' Emergency Reserve was formed with two objects :—

(*a*) To deal with applications for re-employment and appointment to emergency commissions in His Majesty's Land Forces.

(*b*) To maintain a register of retired officers, ex-officers, and others possessing the appropriate military experience or certain technical or other special qualifications, who wish to give an undertaking to present themselves for military service if and when called upon to do so.

Applications may be received from Corporate Members between the ages of 31 and 60 years, but applicants over 55 years of age will only be accepted provided that they possess special qualifications or experience.

Upon being accepted for registration in the Army Officers' Emergency Reserve, members will be notified of that fact by the War Office, and will normally be requested to attend at a Reception Unit for an interview and for medical examination, after which they will be informed of their prospects of employment.

No guarantee can be given that immediate use will be made of the

ervices of all members of this Reserve. Employment will depend on the luration of the war and the nature of the individual's qualifications.

CENTRAL REGISTER OF THE MINISTRY OF LABOUR.

Students of The Institution who are over 23 years of age, and who re not serving in or attested for service with H.M. Forces, may apply o the Secretary for forms for registration with the Central Register.

MILITARY SERVICE.

NATIONAL SERVICE (ARMED FORCES) ACT, 1939.

Students of The Institution who are under 23 years of age and who re liable for Service under the National Service (Armed Forces) Act, 939, must register at a Local Employment Exchange when their age-roup is called, and may obtain from the Secretary a form of certificate ndicating their connexion with The Institution, which, upon production to he Interviewing Officers when their age-groups are called, will, it is nticipated, assist them in being posted to the ranks of the Corps of Royal Engineers or to a technical unit in which their qualifications can be mployed.

Students who are over 23 years of age when their age-groups are alled under the Act must likewise register at a Local Employment Exchange, although they will then be included in the Ministry of Labour's " Schedule of Reserved Occupations." The Secretary will, upon request, urnish such Students with a certificate confirming their connexion with The Institution for production to the Registration Officer of the Exchange. This will apply also to Associate Members when they are called in their ge-groups for registration.

The age-limit of 23 years referred to above is subject to change.

POSTPONEMENT OF ENLISTMENT.

Students of The Institution who are liable for compulsory service in I.M. Forces and who desire to apply to have their enlistment postponed for he purpose of sitting for an Institution Examination, should write to the Secretary, giving full details of the Section or Sections of the Associate Membership Examination which they propose to take, age, etc., who will hen advise them as to the procedure they should adopt in order to obtain onsideration of their case for postponement of service.

GENERAL ANNOUNCEMENTS.

TEMPORARY MODIFICATIONS IN THE BY-LAWS TO MEET WAR CONDITIONS.

The Council have to inform the members and Students that consideration has been given to the need for temporary modifications in the By-Laws to meet conditions arising from the war. The Council felt that, as these modifications were of immediate moment for the benefit of the members and Students affected by the war, it was inconvenient in the present circumstances to use the procedure provided in the Third Supplemental Charter and the By-Laws of The Institution, since experience has shown in the past that the procedure so provided for involves a delay of not less than 6 months. The Council accordingly made application to the Lord President of the Privy Council under the Chartered and Other Bodies (Temporary Provisions) Act, 1939, to give directions under the Act for the necessary temporary modifications during the war period.

Appended is a letter from the Privy Council acceding to the desired modifications.

The Secretary,
The Institution of Civil Engineers.

Privy Council Office,
S.W.1.
16 *January*, 1940.

Sir,

In reply to your letter of the 29th December, I am directed to inform you that the Lord President of the Council, in pursuance of the powers conferred upon him by the Chartered and Other Bodies (Temporary Provisions) Act, 1939, and the Order in Council made thereunder, has been pleased to direct as follows :—

"For the period during which the Chartered and Other Bodies (Temporary Provisions) Act, 1939, remains in force and notwithstanding anything contained in the Charter, By-Laws or Regulations of the Institution of Civil Engineers, the Council of the Institution shall be empowered :—

(1) to accept military or national service approved by the Council as being in whole or in part a fulfilment of the conditions laid down with respect to training and experience under Corporate Members of The Institution or others, and of the conditions as regards Pupilage, Apprenticeship, or other practical engineering service ;

(2) to exempt from examinations of the Institution candidates who have been engaged in military or national service approved by the Council for a period of at least one year and who produce such evidence as the Council may deem sufficient to prove a satisfactory standard of attainment in the subjects of the said examinations ;

(3) to reduce the number of signatures to complete a Proposal for Election in the case of a candidate serving in H.M. Forces to 1 Proposer and 2 others ;

(4) to remit, or to extend the period allowed for the payment of Admission Fees, Transfer Fees and Subscriptions, as well as of arrears of Subscriptions, by any persons who are in military or national service approved by the Council, or who are suffering financially from conditions due to the present war, and who may request the Council to exercise such consideration.

(5) to extend the age limit of Students of The Institution who are serving in any of H.M. Armed Forces, or national service approved by the Council, from 28 to 30 years of age.

(6) to defer at the discretion of the Council the appointment of a second or Honorary Secretary in addition to the acting Secretary who is designated as ' the Secretary.'
(7) to hold the Annual General Meeting on such a date and at such a time and place as may be determined by the Council."

I am, Sir,
Your obedient Servant,
(Signed) RUPERT B. HOWORTH.

A Standing Committee of the Council will scrutinize all applications or election or admission made by those who are engaged in military or other approved national service in order to ensure that the educational and practical attainments of those who enter The Institution shall be such as to qualify them for recognition as members of the Engineering profession.

(*Note.*—It may be mentioned that the modifications numbered (1), (2), (3), (4), are similar to the powers conferred by the members upon the Council in the Great War of 1914–18.)

ELECTION OF COUNCIL.

The Council give notice that in selecting the names of Corporate Members to appear on the Balloting-List for the election of the Council for the year 1940–41, in accordance with the provisions of the By-Laws, they will be pleased to consider any names which may be suggested by individual Corporate Members, provided that the names are communicated to the Secretary on or before Friday, 1 March.

The consent of each person proposed must first be obtained by the Corporate Members submitting names, and they must also state the occupation of the person proposed, namely, whether in practice, or holding an official position, or in other employment.

THE RIGHT HON. SIR JOHN C. W. REITH, P.C., G.C.V.O., G.B.E., M. INST. C.E.

The Council have sent a letter of congratulation to Sir John Reith on his appointment as Minister of Information. This is the first occasion on which a Corporate Member of The Institution has entered the Cabinet, a distinction which the engineering profession regard with pride and satisfaction.

ABSTRACTS.

The publication of " Engineering Abstracts " in sectional form has been suspended. A selection of brief abstracts of important Papers and articles appearing in the home and foreign technical literature dealing with Engineering Construction, Mechanical Engineering, and Mining Engineering is now included in the Journal.

Abstracts of the technical press on Shipbuilding and Marine Engineering (formerly Section 3 of " Engineering Abstracts ") will continue to be

compiled by the Institute of Marine Engineers, and members will be able to obtain these at half the usual subscription rate.

By arrangement with the Institution of Municipal and County Engineers, members are enabled to obtain copies of " Road Abstracts ", compiled by the Department of Scientific and Industrial Research and the Ministry of Transport, at one-half the usual rates charged.

Members are also able to obtain copies of " Building Science Abstracts ", compiled by the Building Research Station, Watford, and of the " Summary of Current Literature " issued by the Water Pollution Research Board, at the special rates detailed below, provided that the order is placed through the Secretary of The Institution.

The subscription rates for 1940 are as follows :—

Shipbuilding and Marine Engineering Abstracts	12*s*. 6*d*. (postage free)
Road Abstracts	8*s*. 6*d*. (postage free)
Building Science Abstracts	14*s*. 6*d*. (postage free)
Water Pollution Research: Summary of Current Literature	18*s*. 6*d*. (postage free)

All subscriptions run from January.

RECORD OF PROFESSIONAL CAREERS.

The Council were gratified by the response made by members to the request for particulars of individual careers set out on the Career Schedule forms issued from The Institution in 1938 and 1939. The Index which has been compiled from the information thus given has already proved to be most useful, not only as a valuable addition to The Institution records, but as one of the means whereby The Institution has been able to give assistance to the Government in connexion with civil engineering services involved in national requirements.

There remains, nevertheless, a percentage of the members who have not returned the Career Schedules. The Council would urge such members to supply the required information, in order that the Institution Index may be as complete as possible. The necessary Career Schedule form can be obtained on application to the Secretary.

The opportunity is taken to ask members to keep The Institution informed of important extensions of professional experience subsequent to the completion of the Career Schedule, so that the individual records may be kept up to date.

It will be helpful if all communications on this subject are headed " Index of Careers."

APRIL, 1940, EXAMINATIONS.

The next Examinations in London and the Provinces are to be held during the week commencing on Monday, 15 April. Intending candidates

are reminded that applications must be received by the Secretary not later than the 28th February, and that Students of The Institution entering for the Associate Membership Examination are recommended to lodge their applications about a fortnight before that date.

CHARLES HAWKSLEY PRIZE FOR 1940.

Competitors are reminded that designs must be received by the Secretary not later than the 29th February.

CHANGES OF ADDRESS.

Owing to the number of changes of address incidental to service with H.M. Forces, it is not practicable to register such addresses in the List of Members. It is therefore suggested that a home (private) address be maintained, from which communications issued by The Institution might be re-directed. If, however, this is impracticable, The Institution may, in special circumstances, arrange for the dispatch of the Journal as issued to a service address.

SERVICE IN THE FORCES.

For office purposes, a record is being kept of members' service with H.M. Forces, and members who have not already done so are asked to inform the Secretary of such service, i.e. unit, rank, promotions, decorations, etc.

THE MYDDELTON CUP.

It had been arranged that in September last representatives of The Institution should visit the United States in response to an invitation from the American Society of Civil Engineers, but, having regard to the international situation, the visit was cancelled.

Had the visit taken place, it was intended that Mr. W. J. E. Binnie, who was then President of The Institution, should present to the American Society of Civil Engineers a replica of the Myddelton Cup, as a token of the friendly relations which have ever existed between the two Societies. Lord Lothian, British Ambassador to the United States, has now, however, on behalf of The Institution, handed the replica to Colonel D. H. Sawyer, President of the American Society, at a gathering of the members of that Society held in Washington on Tuesday, 9 January. The original Cup was presented to Sir Hugh Myddelton in 1613 by the Worshipful Company of Goldsmiths of London for his services in providing London with a supply of potable water. It remained in the possession of the Myddelton family until 1922, when it was acquired by the Goldsmiths' Company.

Lord Lothian, in making the presentation, observed that the cup was a fine example of late-sixteenth-century English work, and that the original was shown in the British Pavilion at the New York World's Fair in 1939.

Referring to Myddelton's achievements, Lord Lothian said that King James I conferred a baronetcy on him in 1622, for the following reasons :—

> "1. For bringing to the City of London, with excessive charge and great difficulty, a new cutt or river of fresh water, to the great benefit and inestimable preservation thereof.
>
> "2. For gaining a very great and spacious quantity of land in Brading Haven in the Isle of Wight, out of the bowells of the sea and with banks and dykes and most strange defensible and chargeable mountains, fortifying the same against the violence and fury of the waves.
>
> "3. For finding out, with a fortunate and prosperous skill, exceeding industry, and noe small charge in the County of Cardigan, a royal and rych myne, from whence he hath extracted many silver plates which have been coyned in the Tower of London for current money of England."

Those achievements showed that Myddelton possessed the true character of an Elizabethan Englishman, and that he had his full share of the "enquiring mind" that was the outstanding characteristic of that age. Lord Lothian thought that Myddelton would have felt at home in the company of present-day civil engineers, and therefore on that account he thought that a replica of the Myddelton Cup was a most fitting vessel in which to convey to the American Society of Civil Engineers the warm feelings of esteem and admiration in which they were held by The Institution.

TRANSFERS, ELECTIONS, AND ADMISSIONS.

Since the 19th December, 1939, the following elections have taken place :

Meeting.	*Associate Members.*
23 January, 1940.	41

and during the same period the Council have transferred five Associate Members to the class of Members, and have admitted fifty-four Students.

DEATHS AND RESIGNATIONS.

The Council have received, with regret, intimation of the following deaths and resignations :—

Deaths.

Griffiths, Griffith John. (E. 1914.) (*Member of Council*).	*Member.*
Hunter, Summers, C.B.E. (E. 1910) (*former Member of Council.*)	,,
Jackson, Sir Arthur. (E. 1907.)	,,
Macpherson, Duncan. (E. 1884. T. 1891.)	,,
Swindlehurst, Joseph Eaves. (E. 1886. T. 1900.)	,,
Whyatt, Henry Gilbert. (E. 1892. T. 1913.)	,,
Bell, David Quintin. (E. 1907.)	*Associate Member.*
Blackwood, William, B.Sc. (E. 1928).	,, ,,
Copestake, Henry Goodall, B.Sc. (E. 1914.)	,, ,,
Ellis, Ernest Edward Francis, B.A., B.A.I. (E. 1935.)	,, ,,
Harvey, Thomas Francis. (E. 1892.)	,, ,,
Stokes, Philip Guy Wilmot. (E. 1929.)	,, ,,
Walker, William George. (E. 1895.)	,, ,,

Resignations.

Breithaupt, William Henry. (E. 1908.)	*Member.*
Agli, Henry Coen. (E. 1924.)	,,
Crawford, Leonard George. (E. 1905. T. 1930.)	,,
Davison, Robert, B.E. (E. 1906. T. 1923.)	,,
Ives, Graves William, M.A., M.A.I. (E. 1899. T. 1912.)	,,
Humphries, Albert, C.B., C.B.E. (E. 1915.)	,,
Abington, Myers, M.C. (E. 1928.)	*Associate Member*
Cameron, Archibald Preston, B.A. (E. 1899.)	,, ,,
oodman, James. (E. 1894.)	,, ,,
oodman, Richard. (E. 1894.)	,, ,,
Hilditch, George Walls. E. 1910.)	,, ,,
ore, Percy Philip. (E. 1902.)	,, ,,
uston, William Edward. (E. 1900.)	,, ,,
egge, Charles Norton Llewellin Kidder. (E. 1916.)	,, ,,
ingard, Aubrey Lawrence, B.A. (E. 1917.)	,, ,,
Mackie, Douglas Runnel. (E. 1915.)	,, ,,
ickering, William Todd. (E. 1898.)	,, ,,
ortsmouth, John. (E. 1896.)	,, ,,
owlands, Harold Berkeley, B.E. (E. 1907.)	,, ,,
almon, Charles Emile Herbert. (E. 1902.)	,, ,,
mith, James Gould. (E. 1894.)	,, ,,
tuart, Donald Macdonald Douglas. (E. 1906.)	,, ,,
tkinson, Myles Birkett, B.A. (A. 1934.)	*Student.*

RECENT ADDITIONS TO THE LIBRARY.

[Journals, Proceedings of Societies, British Standard Specifications, etc., are not included.]

AIR. BOTLEY, C. M. "The Air and its Mysteries." 1938. Bell. 8*s*. 6*d*.

AIR-DEFENCE. *D.S.I.R. BUILDING RESEARCH. Library. Bibliography No. 44, "Air Raid Protection." Abstracts of published papers. 1939.

ARC CONVERTERS. RISSIK, H. "The Fundamental Theory of Arc Converters." 1939. Chapman & Hall. 18*s*.

A theoretical study of the principles underlying the design and operation of arc converter circuits, the Author's object being to present a clear exposition of the functions of the several elements constituting the rectifier circuit in all its forms.

ARMAMENTS. LOW, Prof. A. M. "Modern Armaments." 1939. J. Gifford. 8*s*. 6*d*.

The subject is dealt with in a simple and popular manner, and covers the evolution, manufacture, and use of weapons of offence and defence, including large and small guns, explosives and ammunition, chemical warfare, tanks, armoured cars, naval craft, aircraft, and range-finding apparatus; the adaptation of weapons to peace-time uses is also discussed.

BIOGRAPHY. *"Who's Who, 1940." 1940. A. & C. Black. 63*s*.

The 1940 edition (92nd year of issue) has been expanded to 3,531 pages of biographies of living persons, whilst 12 pages of recent obituary records are also included.

CANALS. *See* FLOW OF WATER.

CUTTING TOOLS. SANDY, A. H. "Cutting Tools for Engineers." 1939. Crosby Lockwood. 3*s*. 6*d*.

FIREARMS. GUNTHER, J. D., and C. O. "The Identification of Firearms from Ammunition fired therein, with an Analysis of Legal Authorities." 1935. Chapman & Hall. 20*s*.

FLOW OF WATER. SCOBEY, F. C. "Flow of Water in Irrigation and similar Canals." 1939. United States Department of Agriculture Technical Bulletin No. 652. Superintendent of Documents. Washington. 20 cents.

FURNACES. BUELL, W. C., Jr. "The Open-Hearth Furnace." Vol. 3. 1939. Penton Publishing Co. 18*s*. 6*d*.

The upper furnace was dealt with in Volumes 1 and 2. In Volume 3 a comparison is made of the "ancillary" (below charging-floor) systems, and the development of basic design principles is discussed. The Author deals in detail with checkerwork and recuperative and regenerative effects therein, flues, valves, and waste-heat boilers.

GASES. D.S.I.R. "Methods for Detection of Toxic Gases in Industry. Leaflets Nos. 8 and 9—Arsene and Phosgene." 1939. H.M.S.O. 2*s*. 6*d*. each.

These leaflets form part of a series describing simple and rapid means of measuring low concentrations of poisonous gases produced in industrial processes.

GAS-FITTING. LEFEVRE, R. N. "A Manual of Practical Gas-Fitting." 1939. W. King. 7*s*. 6*d*.

GRANITE. GEOLOGICAL SURVEY OF SCOTLAND. "The Granites of Scotland." (Memoir vol. xxxii.) 1939. H.M.S.O. Edinburgh. 2*s*. 6*d*.

HEATING. HICKMOTT, J. R. "Water Heating by Electricity." 1939. P. Marshall. 1*s*. 6*d*.

HYDRAULIC JUMP. LEE, C. C. "The Hydraulic Jump. A Bibliography of books, periodicals and society publications from 1819 to 1937." 1937. U.S. Waterways Experiment Station, Vicksburg.

LAND WARFARE. PORTWAY, D. "Science and Mechanisation in Land Warfare." 1938. Heffer. 6*s.*

A comprehensive survey is given of the various ways in which science is applied to war, including the use of railways, mechanization, chemical warfare, weather problems, artillery surveys, and the work of the Royal Engineers and the Royal Corps of Signals.

LOCOMOTIVES. MARSHALL, C. F. D. "Early British Locomotives." 1939. Locomotive Publishing Co. 12*s.* 6*d.*

LUBRICATION. CLOWER, J. I. "Lubricants and Lubrication." 1939. McGraw-Hill. 33*s*

A practical treatise for buyers, sellers, and users of lubricants, and for machine designers and operators, covering the fundamentals of lubricants and lubrication, and dealing in detail with the lubrication of turbines, compressors, and both steam and internal-combustion engines.

MACHINE-TOOLS. BURGHARDT, H. D. "Machine-Tool Operation." Part 1.—Lathe, Bench and Forge. Part 2.—Drilling, Planing, etc. 2nd ed. 1937. McGraw-Hill. 13*s.* 9*d.* and 16*s.* 6*d.*

MEANDERING OF STREAMS. *See* RIVERS AND STREAMS.

METALLOGRAPHY. GREAVES, R. H., and WRIGHTON, H. "Practical Microscopical Metallography." 3rd ed., revised and enlarged. 1939. 18*s.* Chapman & Hall.

METALS. HUME-ROTHERY, W. "Structure of Metals and Alloys." 1936. Institute of Metals Monograph & Report Series No. 1. 3*s.* 6*d.*

METEOROLOGY. ADMIRALTY. "Admiralty Weather Manual." 1938. H.M.S.O. 10*s.* 6*d.*

—— *See also* AIR.

MINERALS. IMPERIAL INSTITUTE. "The Mineral Industry of the British Empire and Foreign Countries. Statistical Summary (Production, Imports and Exports), 1936–1938." 1939. H.M.S.O. 7*s.* 6*d.*

OPERATION-ANALYSIS. MAYNARD, H. B., and G. J. STEGEMERTEN. "Operation Analysis." 1939. McGraw-Hill. 18*s.*

The purpose of this book is to describe the procedure for conducting systematic analyses of existing production methods and processes, and to demonstrate that the results obtainable in production increases are often equal to or greater than those which would result from the installation of new machinery.

PERMANENT-WAY. GOVERNMENT OF INDIA. Railway Dept. "Track Stress Research, November 1935–November 1938. Progress Report." 2 vols., by W. E. Gelson and E. A. Blackwood. Calcutta, E. Indian Rly. Press. 1939. 16*s.*

The Report deals with research on the increment of rail-stress due to the passage of a wheel load on a rail, the conditions of support at rail-joints, the stability of ballast, and the effects of lateral forces on rails arising from the hunting movement of locomotives at speed on straight and on curved track. Volume 2 consists entirely of appendixes to the Report.

POWER-STATIONS. PARSONS, R. H. "Early Days of the Power Station Industry." 1939. Camb. Univ. Press.

The Author traces the origins and the development of the industry, describes various systems of generation and distribution of early undertakings, and describes the types of machinery with which their power-stations were equipped. Accuracy in detail is ensured by systematic reference to contemporary records.

PUBLIC WORKS. PUBLIC WORKS, ROADS AND TRANSPORT CONGRESS. "Papers." 1939. 84 Eccleston Square, S.W.1.

RAILCARS. KIDNER, R. W. "The Railcar, 1847–1939." 1939. Oakwood Press, Sidcup. 5*s.* 6*d.*

RIVERS AND STREAMS. TIFFANY, J. B., and NELSON, G. A. "Studies of Meandering of Model Streams." 1939. (Reprint from *Transactions* American Geophysical Union.) United States Waterways Experiment Station, Vicksburg.

ROADS AND STREETS. PERMANENT INTERNATIONAL ASSOCIATION OF ROAD CONGRESSES. "8th Intl. Road Congress, The Hague, 1938. Report of Proceedings of Congress." Rennes, Paris. 1939.

—— PUBLIC WORKS. Roads and Transport Congress. "Papers." 1939.

SEWAGE-DISPOSAL AND SEWERAGE. BRITISH ELECTRICAL DEVELOPMENT ASSOCIATION. "Water Supply and Sewage-Disposal in Rural and Small Urban Districts Report." 1934. Gratis. 2 Savoy Hill, W.C.2.

STATICS. APPLEBY, M. "Elementary Statics. A Text-book for Engineers." 1939. Camb. Univ. Press. 7*s*. 6*d*.

STATISTICS. BAYLISS, C. H. "A Course in Business Statistics. The Elements of Statistical Methods with Exercises and Answers." 1937. Pitman. 3*s*. 6*d*.

—— CONNOR, L. R. "Statistics in Theory and Practice." 3rd ed., 1938. Pitman. 12*s*. 6*d*.

STRENGTH OF MATERIALS. WARNOCK, F. W. "Strength of Materials." 4th ed., 1939. Pitman. 10*s*. 6*d*.

A text-book for engineering students working for degrees and the final examinations of professional engineering institutions. Numerous worked examples taken from recent examination papers are included, together with many exercises, whilst frequent references to published researches are given.

—— WEIBULL, W. "The Phenomenon of Rupture in Solids." 1939. Royal Swedish Institute for Engineering Research, Proc. No. 153. Stockholm.

TIMBER. *See* WOOD.

TIME AND MOTION STUDY. HOLMES, W. G. "Applied Time and Motion Study." 1938. Ronald Press: Machinery Publishing Co. 16*s*. 6*d*.

TOWERS. BRITISH ELECTRICAL AND ALLIED INDUSTRIES RESEARCH COUNCIL. Technical Report F/T 84. "Wind Pressure on Latticed Towers." Test on Models. 1935. 2*s*. 6*d*. 15 Savoy Street, W.C.2.

TOWN AND AREA PLANNING. DAVIDGE, W. R. "Buckinghamshire Regional Planning Report." 1935. County Council Offices, Aylesbury. 10*s*. 6*d*.

—— —— "Cambridgeshire Regional Planning Report." 1934. Camb. Univ. Press. 7*s*. 6*d*.

TRACK. *See* PERMANENT WAY.

TRANSPORT. PUBLIC WORKS, ROADS AND TRANSPORT CONGRESS. "Papers." 1939.

WAR. *See* ARMAMENTS; LAND WARFARE.

WATER-POLLUTION. D.S.I.R. "Report of the Water-Pollution Research Board for the year ended 30th June, 1939." 1939. H.M.S.O. 1*s*.

The Report summarizes the results of the various investigations made by the Department during the year ended 30th June, 1939.

WATER-SUPPLY. BRITISH ELECTRICAL DEVELOPMENT ASSOCIATION. "Water Supply and Sewage-Disposal in Rural and Small Urban Districts. Report." 1934. 2 Savoy Hill, W.C.2. Gratis.

WEATHER. *See* METEOROLOGY

WIND AND WIND-PRESSURE. *See* TOWERS.

WOOD. D.S.I.R. "Report of the Forest Products Research Board for the year 1938." 1939. H.M.S.O. 1*s*. 6*d*.

WOOD. HENDERSON, H. L. "Air Seasoning and Kiln Drying of Wood." 2nd ed. 1939. J. B. Lyon Co., Albany, N.Y. 16*s*.

The subjects covered include yard seasoning and the staining of lumber during air seasoning, the methods of piling lumber for kiln drying, the drying process, and the types, construction, and operation of drying-kilns.

(* *The foregoing books, with the exception of those marked with an asterisk, may be borrowed from the Loan Library.*)

LOCAL ASSOCIATIONS.

MEETINGS.

The following meetings have been arranged :—

Glasgow and District Association.

Feb. 16. "Hydro-Electric Developments in Britain and the Empire", by James Williamson, M. Inst. C.E. (to be held at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, Glasgow, at 6.30 p.m.)

Northern Ireland Association.

Feb. 26. "Concrete and the Resident Engineer", by D. F. Wilkin, B.Sc., Stud. Inst. C.E.

Mar. 11. Vernon-Harcourt Lecture on "The Construction of Deep-water Quays", by A. C. Gardner, M. Inst. C.E. (to be read by R. D. Duncan, B.Sc., M. Inst. C.E.).

Apr. 8. Annual General Meeting and "The Institution Research into the Deterioration of Structures Exposed to Sea-action", by Professor A. H. Naylor, M.Sc., M. Inst. C.E.

Southern Association.

Feb. 22. "A Brief Survey of Dredging Operations", by M. G. J. McHaffie, M. Inst. C.E. (Southampton).

Mar. 7. Lecture on the Boulder Dam, illustrated by a film and lantern slides (Brighton).

REPORTS.

Birmingham and District Association.

A joint meeting with the Midland Counties Branch of the Institution of Structural Engineers was held on Thursday, 11 January, when a Paper on "The Mechanics and Physics of Rainfall" was read by Mr. D. G. Bevan, M. Inst. C.E.

Edinburgh and District Association.

On Wednesday, 17 January, Mr. A. R. Pollard, B.A., M. Inst. C.E., read a Paper on "Some Floodwork in 1916 in Mesopotamia."

Yorkshire Association.

On Saturday, 6 January, at Sheffield, a Paper on "West Riding County Road Bridges" was presented by Mr. H. A. Whitaker, M. Eng., Assoc. M. Inst. C.E., and members of the staff of the West Riding Surveyor.

ASSOCIATION OF LONDON STUDENTS.

A Meeting of the Association of London Students was held at the Institution on Friday, 5 January, at 5.30 p.m., when about eighty Students were present, on the invitation of Sir Clement Hindley, President, for an informal talk.

Sir Clement, in addressing the Students, said that he was very pleased at the large attendance in response to his invitation and welcomed the opportunity of having an informal talk. He referred to the anxiety of the Council lest the requirements of the present military effort should impair the opportunities for education and training of Students, in which The Institution always took the keenest interest. It was notorious that under present conditions in Germany there was serious interference with the scientific education and training of young men, and the effect on future progress could not be other than disastrous. While no one could deny the vital importance of pursuing the war with all possible energy, it was the hope of all engineers that the maximum effect could be sustained without too seriously encroaching on the time available to Students to acquire the necessary fundamental knowledge and training to fit them for their work, both in the war and after.

He urged on the Students the necessity of taking every opportunity of acquiring knowledge and experience while yet there was time, so that they could be not only of use in whatever military positions they were called on to fill, but could also take their proper places in the work of reconstruction after the war was won. He reminded the Students that The Institution aimed not only at high technical standards but high ethical standards, and he asked them to bear in mind, throughout their career, the reputation which Civil Engineers had established for incorruptibility in their work. They should remember that they had a great responsibility for preserving the traditions of The Institution, and he hoped that wherever they found themselves they would carry that feeling of responsibility with them.

He hoped that the Committee of the Association would consider the question of resuming meetings during the current Session, in regard to which the Secretary would give all possible assistance.

In conclusion, Sir Clement explained broadly how The Institution had endeavoured to assist their Students as well as their members in obtaining suitable technical employment in H.M. Forces.

After Mr. C. H. Copeland, of The Institution's staff, had given a detailed description of the present position in regard to the military obligations of Civil Engineering Students and matters of procedure in regard thereto, those present were invited to ask questions on that subject. A considerable number of questions were put and replied to, and many difficulties that had occurred were dealt with.

ABSTRACTS OF PAPERS FOR DISCUSSION.

The following Papers will be brought forward for discussion on the
tes indicated in the margin of the abstract, and will be published, with
ports of the oral and written discussions upon them, in the Journal.
mbers desiring to take part in the consideration of these Papers should
ply forthwith for advance copies, which will be forwarded as soon as
y are ready. Applications for proofs should be made on postcards,
oting the number of the Paper.

A period of about 3 months from the date of publication of the Paper
the Journal is generally allowed for written communications, which
uld be :—

(*a*) As concise as possible and entirely relevant to the subject-matter of the Paper ;

(*b*) Written legibly or typed with the lines openly spaced.

Paper No. 5217.

To be read on 20/2/40.

"The Dragline Excavator."

By William Barnes, M.I.Mech.E.

Part I of the Paper describes the different forms of construction of
gline excavators, and discusses the relative merits of each type with
rence to size and strength of brackets, working ranges, and digging
vers and speeds. Part II describes, with the aid of many photographs,
way in which the dragline excavator is adaptable to almost any type of
avating work. Tables, showing comparisons of working costs on
eral large undertakings, show the main reasons for the increasing use of
dragline as an excavating machine.

Paper No. 5216.

To be read on 19/3/40.

"The Sewage Disposal of Delhi."

By John Aldhelm Raikes Bromage, M. Inst. C.E.

The Paper first outlines the history of the sewage disposal of the city
elhi and shows how the new works had become an urgent necessity in
of the unexpectedly rapid increase of population. The duplication
ome of the existing works is discussed, and then the Paper describes, in
il, the construction of the new "Simplex" plant, including the pre-
nary settling tanks, the aeration tanks, and the final settling tanks.
arate sections deal with the power-supply, chlorination, storm-water,
ancillary buildings. Operating results are tabulated. The total

cost was £293,000; the work was commenced in December, 1936, and wa put into operation in September, 1938.

To be read on 23/4/40.

Paper No. 5222.

" Remodelling of the Assiut Barrage, Egypt."

By JOHN EDWARD BOSTOCK, O.B.E., M. Inst. C.E.

The Paper refers briefly to the construction of the original barrage an head regulator of the old Ibrahimia canal carried out coincidently with th Aswân dam in 1898–1902. The condition of the original work afte 35 years of use is described. The main items of the new work are deal with, including: the strengthening and extension of the lock walls an approach floors; the lengthening of the one hundred and ten piers an arches and widening of the roadways; the construction of new granite sill and floors in the sluices; the provision and erection of new sluice gates an operating machines; the construction of concrete impermeable floors flexible concrete-block aprons and toes on both sides of the barrage; th systematic grouting of the old and the new work; the provision an erection of new lifting-leaf roadway bridges; the overhaul and repair o the existing lock gates and gear. Two novel items are also describec These are the transverse cementated cut-offs at four places below the origina barrage floor, and a reinforced-concrete interlocking piled cut-off from en to end of the barrage. The cost of the work was approximately £1,140,00

To be read on 14/5/40.

Paper No. 5233.

" Cliff-Stabilization Works in London Clay."

By JACK DUVIVIER, B.Sc. (Eng.), M. Inst. C.E.

The Paper deals with the cliffs to the east of Herne Bay, where, fo many years, cliff falls have been a matter of great concern and expense In 1936, the interior structure of the cliffs was examined by means o boreholes and from the information so obtained it was evident that th trouble could only be cured by a comprehensive system of deep drainage Work commenced in July, 1937, and included the construction of a dee longitudinal pipe and rubble drain, a number of deep primary drains, an sundry additional works, such as the reconstruction of damaged retainin walls and promenades. The work was completed in October, 1938, at total cost of appxroximately £31,600.
